1972

Artificial structures and microclimate in relation to pheasant nesting

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73-9481

RUSSELL, Kenneth Robert, 1933-
ARTIFICIAL STRUCTURES AND MICROCLIMATE IN
RELATION TO PHEASANT NESTING.

Iowa State University, Ph.D., 1972
Agriculture, forestry & wildlife

University Microfilms, A XEROX Company, Ann Arbor, Michigan

Artificial structures and microclimate

in relation to pheasant nesting

by

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A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of

The Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Department: Zoology and Entomology

Major: Wildlife Biology

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

For the Major Department

Signature was redacted for privacy.

For the Graduate College

Iowa State University
Ames, Iowa

1972

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INTRODUCTION

This study, extending from 1969 to 1971, was concerned with (a) the effects of high temperatures and low humidity on the reproductive success of the ring-necked pheasant (*Phasianus colchicus*), and (b) field tests of artificial nesting structures intended to modify climatic extremes. Romanoff (1934:10) established that 101° F was the most efficient constant temperature for continuous growth and development of the pheasant embryo, and that embryonic mortality increased to 50 percent at 103°, 90 percent at 104°, and 99 percent at 105°. He recorded 40 percent embryonic mortality at 40 percent relative humidity but only 28 percent mortality at 80 percent relative humidity, and concluded (p. 31): "The mortality of pheasant embryos was the lowest at high humidity, and then gradually increased towards low humidity." Thus, a temperature of 101° F at a relative humidity of about 80 percent may be considered to be near optimum for pheasant incubation.

Bennitt and Terrill (1940:428) theorized that high egg temperatures limit the southern extension of pheasant range and when lethal temperatures occur on successful range the result is a shortage in the production of pheasants. Climatographs prepared by Graham and Hesterberg (1948:10) showed coincidence of April 1 to June 1 temperature and precipitation characteristics in successful pheasant range, and from these, they reasoned that the limiting effects of temperature and precipitation were manifested prior to hatching, particularly during the egg-laying period. During that period "... the eggs are exposed to direct solar radiation unless, by chance, they happen to be placed in an unusual shady spot." More recently, Dahlgren (1967:12) associated high temperatures with poor pheasant reproduction in South Dakota in 1950, 1959 and 1964.

Published records of dead embryos found in nests where some of the eggs hatched but others did not, further reflect the effects of high temperature and low humidity on pheasant reproduction. Hamerstrom (1936:181) reported the 12.2 percent dead embryos he found in 1934 might be attributable to drought conditions, though in 1935, a somewhat wetter than normal season, 14.0 percent of the embryos in successful nests were found dead. From data published by Baskett (1947:19) it was possible to calculate that the known numbers of unhatched eggs (including infertile eggs) in successful nests that he found in north-central Iowa were 15.4 percent in 1939, 17.4 percent in 1940, and 17.9 percent in 1941. He felt that those embryos that died in early incubation probably did so because the females were kept off the nest for extended periods during very hot weather.

Central Illinois studies revealed sharp decreases of successful hatches and in number of young per brood about the first week of July according to Yeatter (1950:529). He believed that decrease was chiefly the result of a decline in the hatchability of the eggs, and stated that 43 percent of the fertile eggs in 16 nests "... where some young had hatched after July 1 contained dead embryos, usually at a very early stage of development." He added that a number of subnormal young which died in the nests or soon after leaving them had been found in late hatches also. Data for Minnesota (Chesness et al., 1968:693) suggest 12 percent of the eggs in successful nests found in studies there did not hatch. No references were found that included data on the number of complete clutches that had failed to hatch because of embryonic mortality or the number of unhatched eggs that had been removed by predators after part of the clutch had hatched but before discovery by investigators.

Drought conditions, characterized by low humidity and often high temperatures, have been thought to be the cause of pheasant population declines by a number of workers. Hamerstrom (1936:184) attributed a 1934 population low in northwest Iowa to drought as did Bennett and Hendrickson (1938:723) another Iowa population drop in 1936. In discussing a pheasant population decline in the 1940's, Kimball (1948:309) noted that populations did not generally increase when June weather was either wet and cold or exceptionally hot and dry. He had stated earlier (p. 300): "Of all pheasant mortality factors, egg mortality appears to be the greatest, the most variable, and the one most likely to have caused the present pheasant population decline."

Similar conclusions were reached in the late 1960's by others. Martinson and Grondahl (1966:79) concluded that, "... 2 consecutive years of dry weather (1958 and 1959) effected a pronounced decrease in pheasants throughout southwestern North Dakota." They further noted that high productivity of pheasants was associated with high precipitation (e.g. 7, 8 and 9 inches of rain in May and June). With respect to South Dakota, Dahlgren (1967:16) maintained: "A one-year drought in our modern day and age has a disastrous effect on the pheasant population, not only for that year, but for the next." Further east, Russell (1968: 263) presented data from northwestern Ohio showing highly significant correlations between pheasant population declines and rainfall deficiencies and concluded that,"... any substantial or sustained deviation from normal of rainfall during the nesting season would likely be followed by a decline in the fall pheasant population." In contrast, Bennett and Hendrickson (1938:723) and Kimball (1948:309), along with many others, have attributed some population declines to excessive precipitation.

The climate near the ground, where the pheasant lives and reproduces, is far different from the climate three feet above the ground. Temperatures can reach 150° F (Klonglan 1962:256), and humidity at ground level can be substantially different than at waist-level depending on soil moisture levels, type and density of cover and wind characteristics. Tanner (1957:221) has explained that,"As the soil becomes drier and the water supply in the soil becomes less available, less of the net radiation is used in evaporation. Consequently, the surface temperature rises, and there is a greater transfer of heat from the hot surface to the air."

With respect to the properties of vegetative ground cover, Shaw (personal communication) has found that the effect of leaf pattern is to make the outer surface of a broad-leaved canopy the effective radiating surface, while, in contrast, in a narrow, vertical-leaved canopy the effective radiating surface is near the top but within the canopy. The resulting effect is the occurrence of maximum temperatures nearer the ground surface beneath a narrow-leaved canopy. Shaw further noted that vegetative cover tends to reduce temperature oscillations within the cover and that a moist soil tends to moderate the temperature and create a more uniform temperature microclimate. If a large part of the energy in the incident radiation is used in transpiration (and evaporation), there is little heating, but if there is little transpiration (or evaporation) considerable heating may take place at the surface.

Within several types of potential pheasant nesting cover, Francis (1968:44) found highest temperatures in central Illinois were encountered in grasses one meter tall. His data showed (p. 45) that, "... there is an overall difference in microclimatic conditions among cover types in the nesting season of May-June-July; that extremes of temperature and of humidity, of magnitudes that may affect hatchability, occur both in the early nesting season and later in the summer; and that the cover types in which pheasant nests are most often found are those in which temperatures and saturation deficits are lowest." It would thus appear that a temperate, moist microclimate would be optimum for successful pheasant nesting. Eklund (1942:227) has stated: "A combination of sun, shade and good cover appears to characterize the ideal habitat."

Unfortunately, the amount of shade and good cover available for pheasant nesting has diminished substantially as agricultural practices have become more intensive. To further compound this situation, most of the quality cover that is attractive to nesting hens is harvested for hay, usually a week or two before most of the nests in hayfields would normally hatch. The consequence is a high rate of nest and hen losses.

Roadsides comprise a second major cover type often used by nesting pheasants, but, as well as often being frequented by ground predators, roadsides are usually deficient in the broad leaved weeds that would provide a shade-producing canopy over the grassy ground cover.

Providing a substitute for the aforementioned missing canopy seemed to be one possible way to create a microclimate that would be attractive to hen pheasants seeking a site for a nest. This approach had the additional potential of attracting hens into locations, such as roadsides, where the cover would remain secure and undisturbed throughout the nesting season. The reduced losses to hay mowing and increased nesting success would ultimately lead to higher local pheasant populations.

Only one other attempt to create artificial nesting structures for pheasants is known to the author. Work was initiated in the Minnesota Department of Conservation in 1967 to develop a structure acceptable to pheasants as a nesting site and to develop "... a captive flock of pheasants imprinted to elevated, artificial nesting structures." That study utilized field pens and yielded the conclusions that pheasant chicks did not appear to imprint to the structures, but that adult hens that used the artificial structures once would most likely use them again (Johnson 1971). The approaches to the Minnesota study and this study were entirely different other than the fact that both involved nesting structures.

The objectives of this study were to (a) evaluate the response of pheasants to artificial structures intended to create a microenvironment preferred for a nesting site, (b) monitor temperature and moisture conditions under the structures and relate them to conditions in natural cover, and (c) measure the pheasant population levels on the study area and relate them to temperature and moisture conditions during the reproductive season.

METHODS

Two types of nesting structures were placed on a study area in southern Hamilton County in 1970 and 1971. Temperature and moisture conditions under the structures and in natural cover were monitored in 1971 and air temperature, soil temperature and precipitation data published for 1969, 1970 and 1971 by the Environmental Data Service were utilized. Pheasant brood counts and spring call counts were made.

The Study Area

The study area encompassed 12 sections in a 3 x 4-mile block in Hamilton County, Iowa. It was located northeast of 94° N. and 42° W., and included sections 18, 19, 30, and 31, T-86-N, R-24-W (Ellsworth Township), and sections 13, 14, 23, 24, 25, 26, 35 and 36, T-86-N, R-25-W (Clear Lake Township). The nearest boundaries were approximately 13 miles north of Ames, 16 miles south-southeast of Webster City and 3 miles southwest of Jewell. This area was selected because of its proximity to Ames and because it was known to support a relatively high pheasant population. Approximately 75 birds per section in early spring were reported for some of the sections during 1966 and 1967 by Egbert (1968:32). All land on the study area is in private ownership.

The soils on the study area were derived from Wisconsin drift and are comprised of (by decreasing area) Webster loam, Carrington loam, Clarion loam, Webster clay loam and a few pockets of peat (Stevenson and Brown 1921). The topography is level to gently rolling and the land use on the study area is entirely agricultural. With the exception of some pastures, associated principally with Kegley Creek, nearly all of the major land units are cultivated for corn, soybeans and oats. Little woody vegetation occurs on the area other than around farmsteads and near Kegley Creek.

Precipitation in the vicinity averages about 29 inches annually, with 3.9, 4.9 and 3.5 inches falling in May, June and July respectively. Temperatures average 19° in January, 48° in April and 74° in July (U.S. Department of Commerce 1971).

Permanent grasses on the study area are almost entirely limited to roadsides with the exceptions of two or three areas too wet for cultivation and an occasional wide fencerow. Smooth brome and bluegrass are dominant but both domestic and native grasses are found locally. A list of the plant species observed on the area appears in Appendix A.

Nesting Structures

Two types of structures were built to provide the shade desired for the study. The shade-producing element for both types was common burlap, sandwiched between two layers of 1-inch poultry netting. One type (hereafter referred to as the flat structure) was 36-inches square and was suspended horizontally about 24 inches off the ground from two, 3/8-inch steel rods by a frame of 1/2-inch wood dowels and stovepipe wire (Figure 1). The second type (hereafter referred to as the hut structure) was 36 x 72 inches, had a portion cut out of both ends, and was erected with both ends on the ground, forming an arch that peaked about 24 inches above the ground (Figure 2).

Figure 1. Experimental flat nesting structure.

Figure 2. Experimental hut nesting structure.

Over 200 structures were field-tested on the study area in 1970 and 1971. They were installed in straight lines, 25 steps apart, with the two types alternated. Roadsides were most commonly involved (Figure 3), but some were placed in fields near the borders. Nearly all of the structures were installed before mid-April in both 1970 and 1971 and each structure was inspected for utilization two or three times during the period from early May to mid-July. Most of the structures were removed from the study area by late July each year and a few were removed as early as late June.

Temperature and Moisture Measurements

Temperatures in the cover under one hut and one flat structure on the Hamilton County study area were recorded continuously and wet and dry-bulb temperature readings were taken frequently from 10 April to 20 July in 1971. Similar data were recorded adjacent to the structures on the study area and in a hayfield on an Iowa State University farm near Ames. The location of the microclimate sampling site near Ames enabled the investigator to obtain wet and dry-bulb readings more often than could have been done economically on the study area.

The microclimate sampling station on the study area was located in a 10-foot wide strip of dense brome and bluegrass between a pasture and a crop field, and near the top of a gentle slope that faced west (Figures 4 and 5). The Ames station was near the center of a 3-acre field of mixed hay (primarily of orchard, timothy, brome and bluegrass, plus some alfalfa and red clover) that was bordered on the north and west by a

Figure 3. Typical installation of a unit of nesting structures, 10 June 1970.

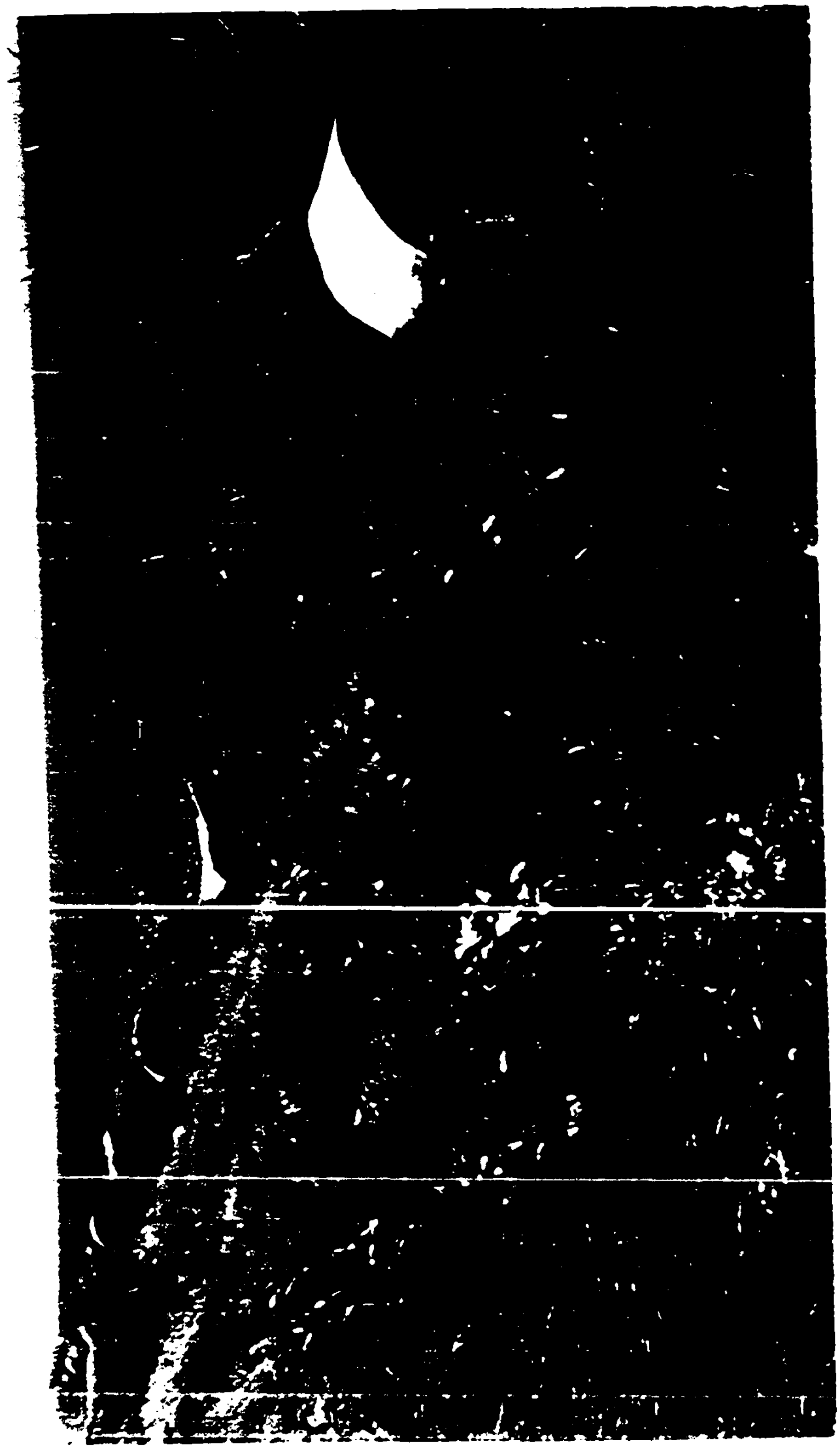
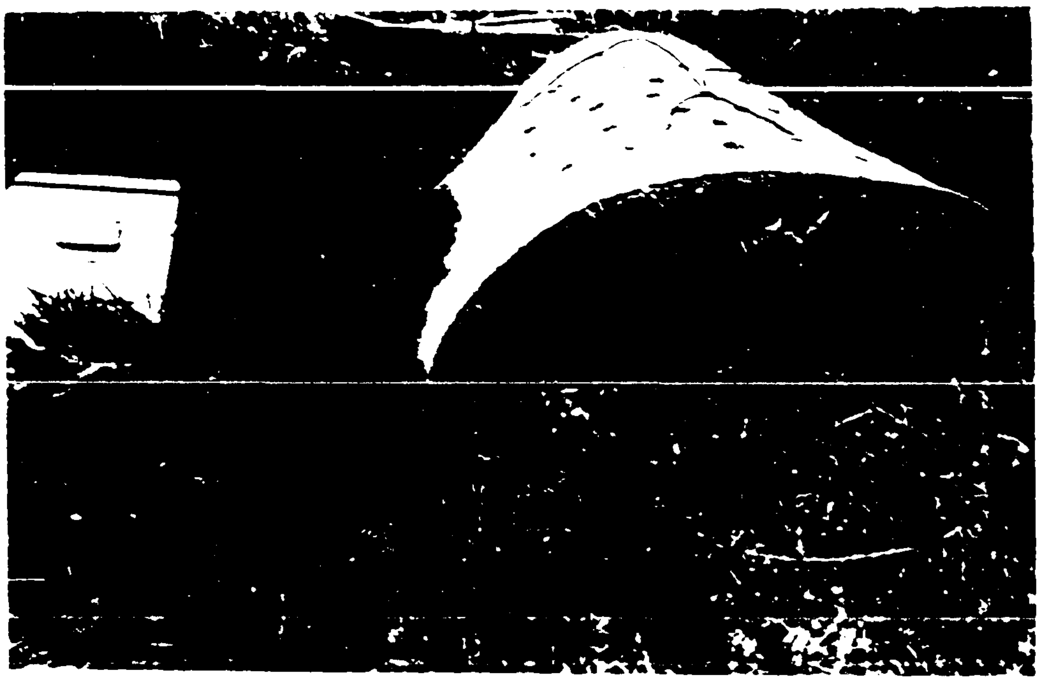


Figure 4. Microclimate sampling station on the Hamilton County study area, 10 April 1971. The recording thermometers were housed in the ventilated styrofoam chest.

Figure 5. Microclimate sampling station on the Hamilton County study area, 29 April 1971.



woodlot, on the east by a gravel road and on the south by an access lane and farm residence (Figure 6 and 7). Both locations were in cover and situations where one might expect to find a pheasant nest.

Four 24-hour and one 7-day recording thermometers were used to measure temperatures at ground level. All five were Marshalltown Manufacturing, Inc. Model 1000's and were equipped with 4-inch sensing probes on 10-foot capillaries (Figure 8). The probes were interwoven through vegetative litter, were in contact with the soil surface and were well concealed by both dead and new growth cover. The 7-day recorder was used in natural cover on the study area. All five thermometers were operated under common conditions before and after the 1971 season to ensure reliability of the readings obtained.

All wet and dry-bulb temperature readings were obtained with a hand aspirated psychrometer, Bendix Corporation model HA-2A (Figure 9). Use of this type of psychrometer made it possible to take readings within heavy cover with the instrument in contact with or within less than one inch of the ground surface.

Vapor pressure deficits (the drying capacity of the air) were calculated from the wet and dry-bulb readings and tables of relative humidity values published by Marvin (1941:57). The relative humidity value so obtained was then multiplied by the saturation vapor pressure value, expressed in inches of mercury (for an atmospheric pressure of 30.0 inches) for that air temperature (Marvin 1941:17). The product of this calculation yielded the actual vapor pressure, which was then subtracted from the saturation vapor pressure to obtain the vapor pressure deficit

Figure 6. Microclimate sampling station at Ames, 10 April 1971.

Figure 7. Microclimate sampling station at Ames, 17 April 1971.

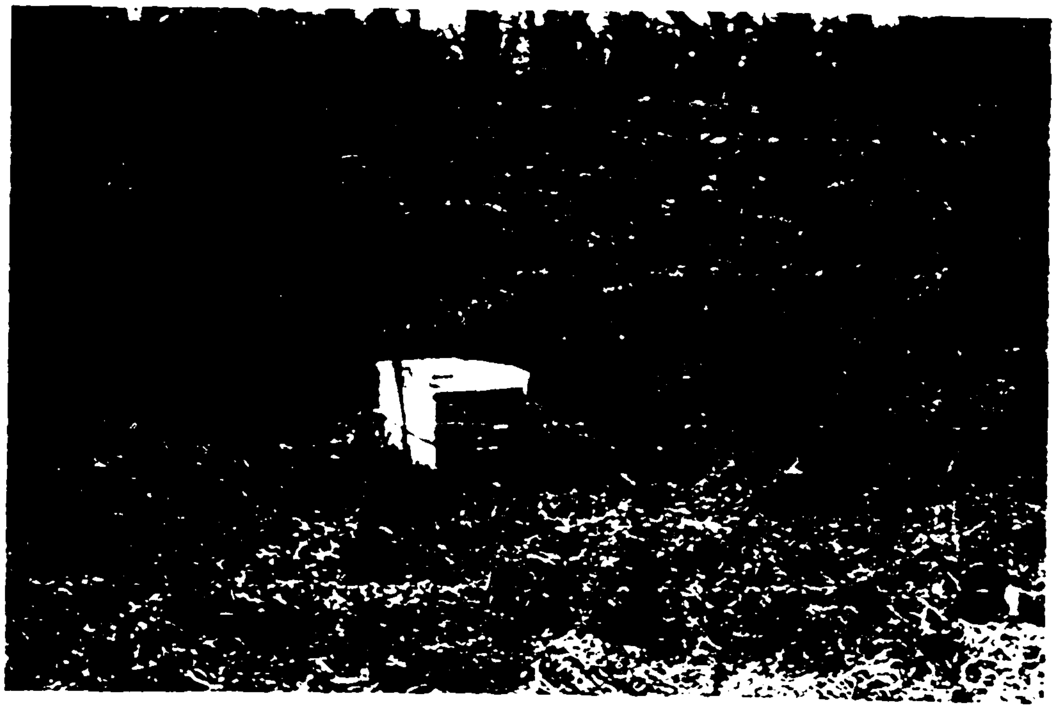
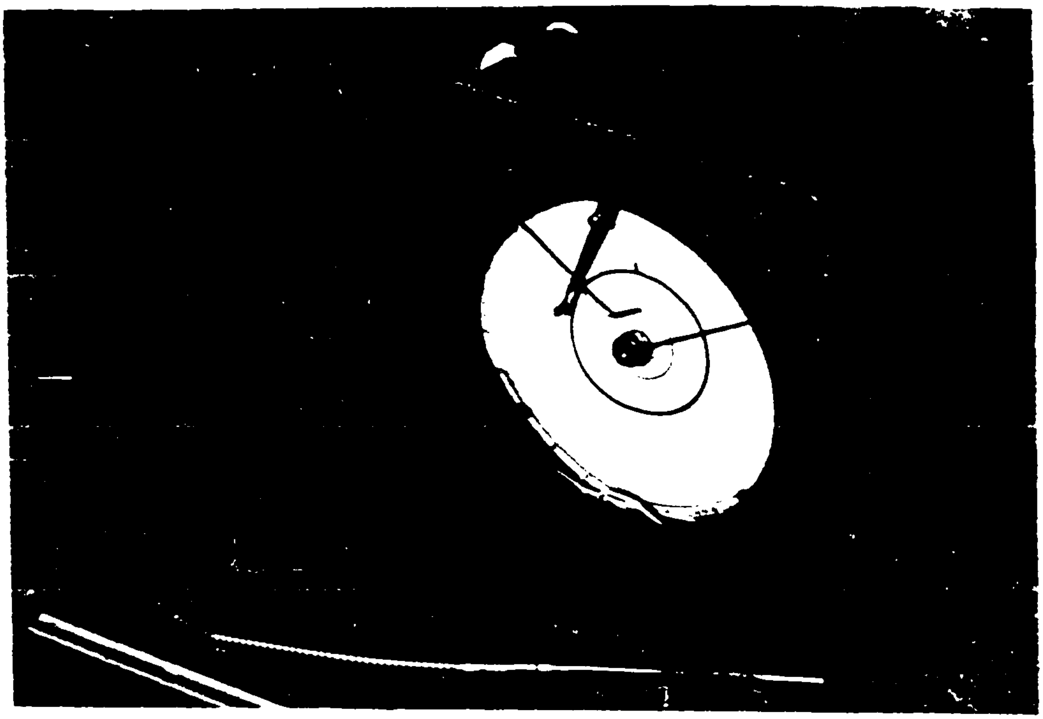
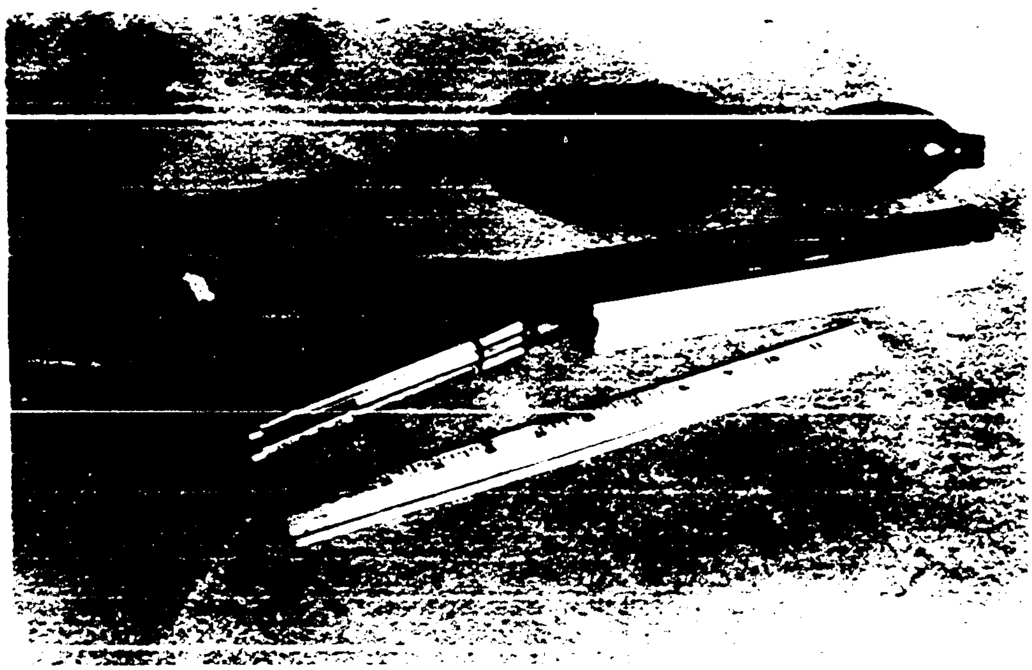


Figure 8. Recording thermometer used at the Hamilton County and Ames microclimate sampling stations.

Figure 9. Hand aspirated psychrometer used at the Hamilton County and Ames microclimate sampling stations.





(Shaw, personal communication).

$$e_a = e_s(rh)$$

$$VPD = e_s - e_a$$

where: e_s is the saturation vapor pressure

e_a is the actual vapor pressure

rh is the relative humidity, $\frac{e_a}{e_s}$

VPD is the vapor pressure deficit

The higher the value of the vapor pressure deficit (saturation deficit) the greater the drying capacity of the air. The saturation vapor pressure depends only on temperature. If the temperature is raised, the saturation vapor pressure increases: if the temperature is lowered the saturation vapor pressure decreases (Penman 1955:11).

Daily maximum and minimum air temperatures, soil temperatures and precipitation for the period 1 March thru 30 August, 1969, 1970 and 1971 were taken from the Climatological Data, Iowa, series published by the U.S. Department of Commerce. Air and soil temperature data were recorded at the Ames station, 8 miles west-southwest of Ames and about 18 miles from the center of the study area. The soil temperatures were from a depth of one inch as registered at 5 pm in bare Clarion loam cultivated to a depth of two inches on a 0° slope. The soil temperatures were used to provide an index of the rate and extent of warming of the soil for the three survey years, with a direct but unspecified relationship to the pheasant nesting microclimate inferred.

The precipitation data were recorded at Jewell, about 5 miles northeast of the center of the study area. No precipitation data for that station were published for June, 1971, so data for the Ames station were substituted. Temperature data were not published for Jewell.

The station nearest the study area for which long-term temperature and precipitation data were published was at Webster City, about 18 miles north-northwest of the center of the study area.

Pheasant Surveys

Summer roadside brood counts made in 1969, 1970 and 1971 were the main sources of population data. Counts were made weekly on or as near Wednesdays as weather permitted, beginning in early June and continuing to as late as September 11. The survey route included every section of road on the study area and totaled 31 miles (Figure 10, page 26). The counts were started at opposite ends in alternate weeks and were made only on mornings when the sky was clear and the wind less than 8 miles per hour. Each survey was started at sunrise, and the route was driven at about 15 miles per hour. All pheasants seen, regardless of their proximity to the road, were recorded as to location, sex, age and number of chicks in the brood.

Pheasant call counts were made between 17 and 24 May in 1970 and between 28 April and 16 May in 1971. Counts were started at 40 minutes before sunrise and extended at one-mile intervals over 10 or 11 stops, depending on the segment being surveyed. Each segment was surveyed twice, beginning at opposite ends of the segment. Call counts were made for two-minute periods at each stop and only on clear mornings when the wind was less than 8 miles per hour. The statistical methods employed in this study follow Snedecor and Cochran (1967) unless otherwise indicated.

RESULTS

Nesting Structures

Two-hundred and twenty-two structures (110 of each type) were installed in 13 units in 1970 and 206 (103 of each type) in 20 units in 1971. The number of structures in a single unit ranged from 8 to 36 in 1970 and from 5 to 22 in 1971. The locations of the structure units on the study area are shown in Figure 10.

Not all structures remained in place to the time of final inspection. In 1970 all 22 structures in an unused pasture were trampled by cattle that had broken through the fence from an adjacent pasture. The structures were repaired but about two weeks later the trampling was repeated and this unit was abandoned. On 31 July 1970 all 14 structures in another unit were found to have been moved to facilitate mowing and could not be included in the final inspection for utilization.

Nesting structure utilization

No indication of a positive response to the structures by pheasants was found during the entire study, although several nests were found in close proximity to structures. One nest was discovered within 3 1/2 feet of a flat structure on 6 May 1970 (Figure 11). That nest contained 11 unincubated eggs which the hen apparently abandoned after being flushed. When revisited one week later the nest had been destroyed by predators. Other nests, (none of which were successful) were recorded 35, 25, 20, 16 and 10 feet from structures.

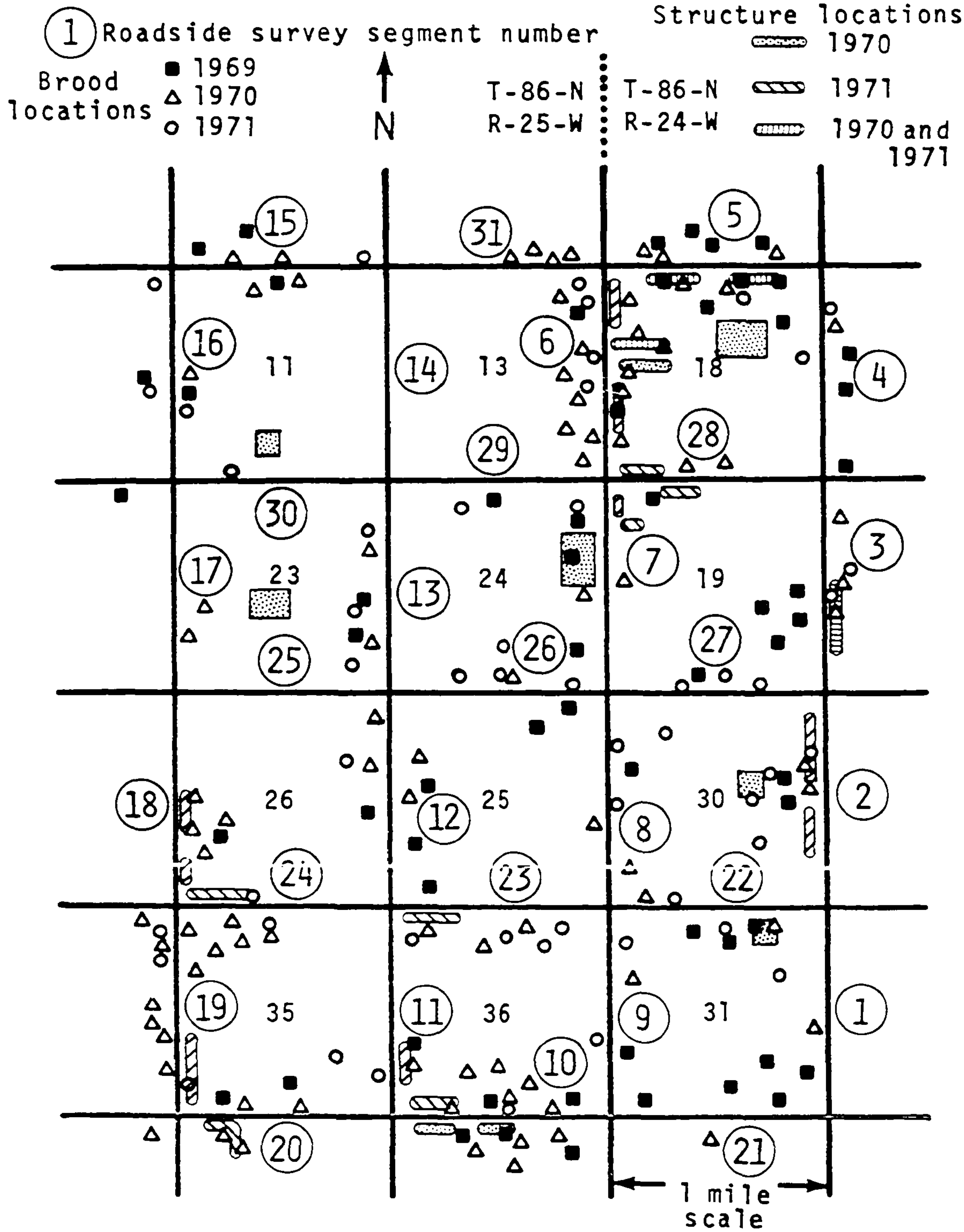


Figure 10. Sites where nesting structures were located in 1970 and 1971 and where broods were seen during roadside pheasant counts on the Hamilton County study area in 1969, 1970 and 1971.

Figure 11. Pheasant nest near flat nesting structure situated in roadside ditch on Hamilton County study area, 6 May 1970. The shadow in the upper-right corner was cast by the structure.

One hen was observed feeding in the vicinity of two structures on 7 May 1971. She casually worked around a hut structure, then followed the fence to the next flat structure, which was over a tall, thick clump of brome grass. She stopped at the edge of the structure, hestitated, then returned on the same path by which she had approached it, eventually crossing the fence into a soybean field. Several other observations were made of both hens and cocks in the immediate vicinity of structures, but they appeared completely indifferent toward the structures in all cases.

A flat structure was placed over a nest after the hen was flushed from it on 2 June 1971. The nest contained 9 eggs at the time and was located in the bottom of a ditch in brome-bluegrass cover. In the course of installing the structure, taking photographs and recording data, some cover near the nest was flattened quite obviously. A path, presumably made by some predator, passed within 4 feet of the nest. One of the eggs was removed, opened, and found unincubated, leaving 8 eggs in the nest. The nest was visited the next day and contained 1 additional egg, and when revisited on 7 June, contained 13 eggs. The hen was observed on the nest again on 21 June and on 28 June. Between 28 June and 1 July, the nest was destroyed by a predator, probably no more than 2 days away from the time the clutch would have hatched. A heavy rain fell the night of 29 June but no evidence of water having collected in the broken shells was found (several shells were in a condition and position to have held water), indicating that the predation occurred the night of 30 June.

Several instances of cottontails (Sylvilagus floridanus) (the scientific names given for mammals are according to Hall and Kelson 1959) using structures were noted. A nest containing 4 young cottontails was found under a hut structure on 11 August 1970. On 6 May 1971 another nest containing an undetermined number of dead young was found under a hut. Two more young (that were partially eaten) were nearby and the carcass of an adult was located about 75 yards away next to a flat structure. Individual cottontails were flushed from beneath structures on several occasions and trails leading to other structures with forms under them indicated use of structures as loafing sites by cottontails was not uncommon.

Predator attention to nesting structures

The carcass of a hen pheasant was found 22 July 1970 under a hut structure where it presumably had been dragged by a predator. No evidence of the hen having roosted there was found under the structure. Fur, believed to be that of a jackrabbit (*Lepus townsendii*), was found under a flat structure on 25 June 1971 and droppings found earlier under a hut structure appeared to have been left by a transient litter of furbearers. Forms found under structures on several occasions were of a size that could have been made by a fox (*Vulpes fulva*) or cat (*Felis catus*).

Four to seven pheasant eggs were placed under each of four structures in widely separated locations on 25 June 1971 to ascertain whether predators were regularly visiting the structures. The eggs, surplus to the propagation operation at the Wildlife Research and Exhibit Station, Iowa Conservation Commission, Boone, were handled with gloves only and were placed under the structures by use of a fully extended golf ball retriever. On 28 June all four sets were still intact and when the structures were removed from the field 1 July 1971, 3 of the 4 sets were complete. No eggs or shells were found under the fourth set, indicating that at least some of the structures were being investigated by predators.

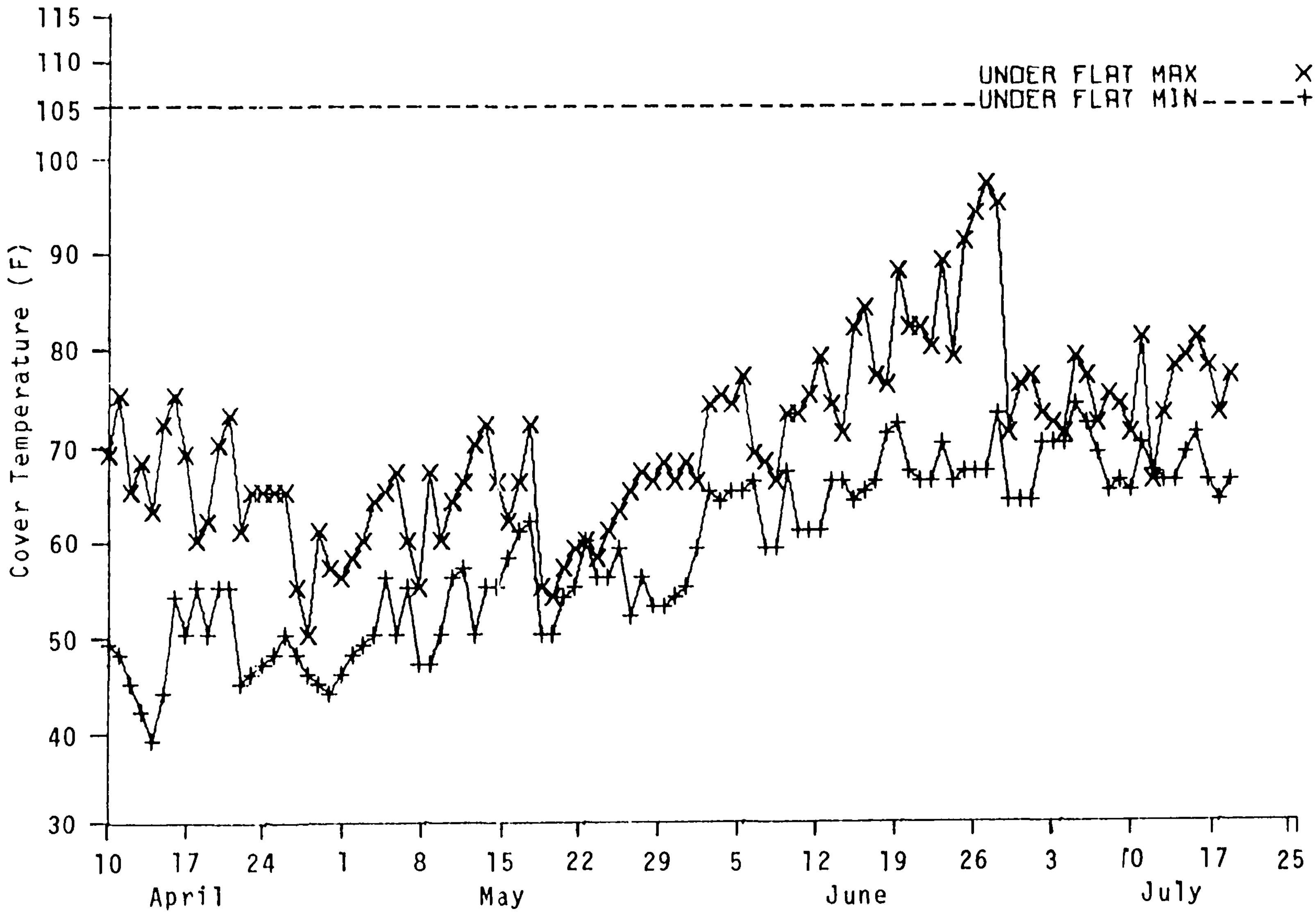
Temperature and Moisture Values

Weather conditions during the 3 years of the study contrasted sharply. The 1969 reproductive season was cool and wet, the 1970 season was normal in terms of temperature and precipitation and the 1971 season was hot and dry.

Cover temperatures

Temperatures were sampled in 5 different locations in 1971 in ground cover of the type often used by nesting pheasants. Profiles of daily maximum and minimum temperatures from 10 April thru 20 July in each of those locations are shown in Figures 12 thru 16 (the dotted line at 105° indicates the temperature where substantial embryo mortality could be expected). Lowest maxima were recorded under the hut structure where the highest temperatures reached were 92, 91 and 90° F. The highest temperatures in all 5 locations were recorded on 28 June, 29 June and 27 June, in that order. The next coolest extremes were under the flat structure (97° F) and in nearby open cover as measured by thermometer A (98° F). Thermometer B registered extremes of 113, 110 and 108° F, though the sensing probe was less than 3 feet away from probe A. The

Figure 12. Daily maximum and minimum temperatures in ground cover under a flat nesting structure on the Hamilton County study area from 10 April to 20 July 1971.



UNDER FLAT MAX
UNDER FLAT MIN
Cover Temperature (F)
115
110
105
100
90
80
70
60
50
40
30
10
17
24
1
8
15
22
29
5
12
19
26
3
10
17
25
April
May
June
July

Figure 13. Daily maximum and minimum temperatures in ground cover under a hut nesting structure on the Hamilton County study area 10 April to 20 July 1971.

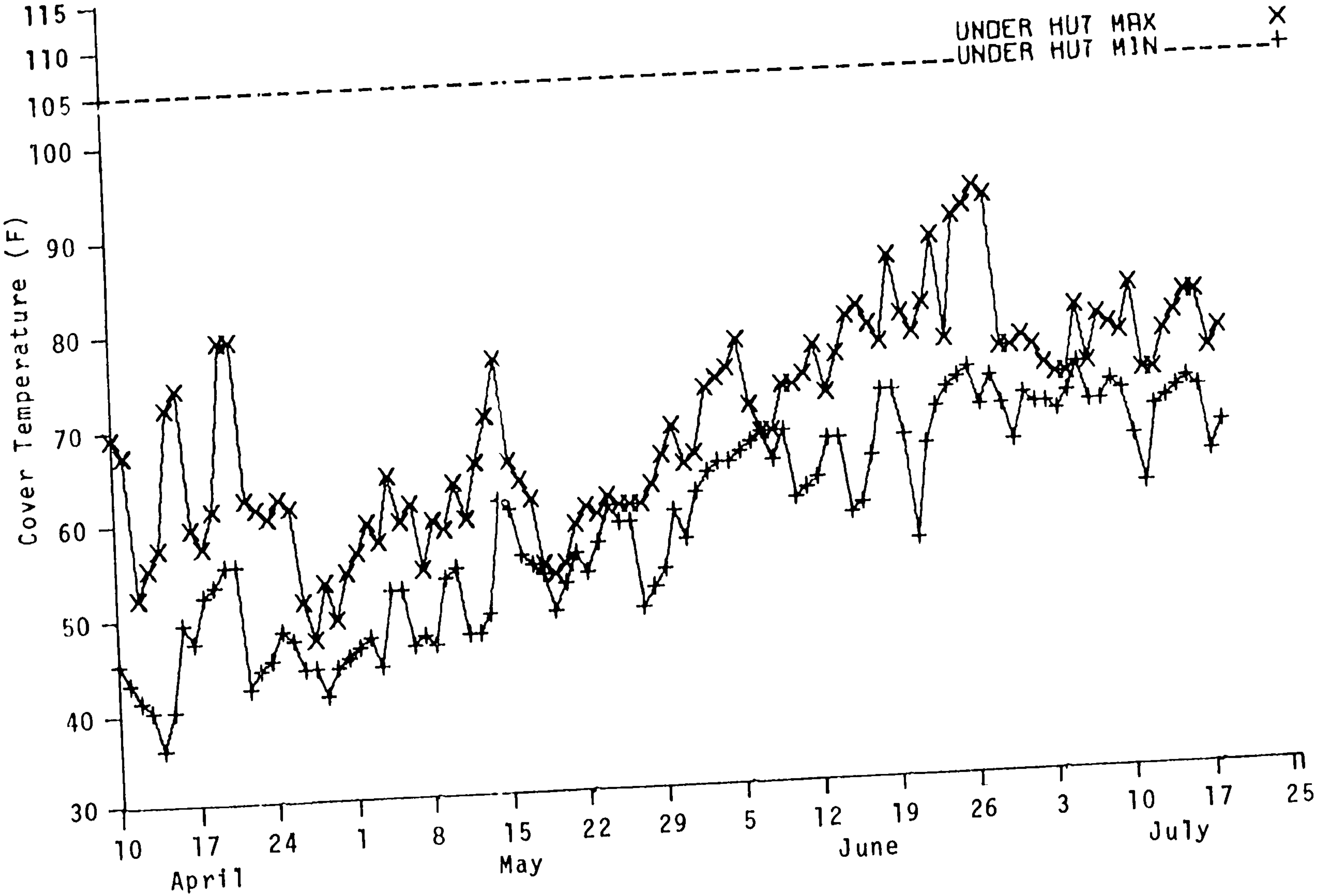
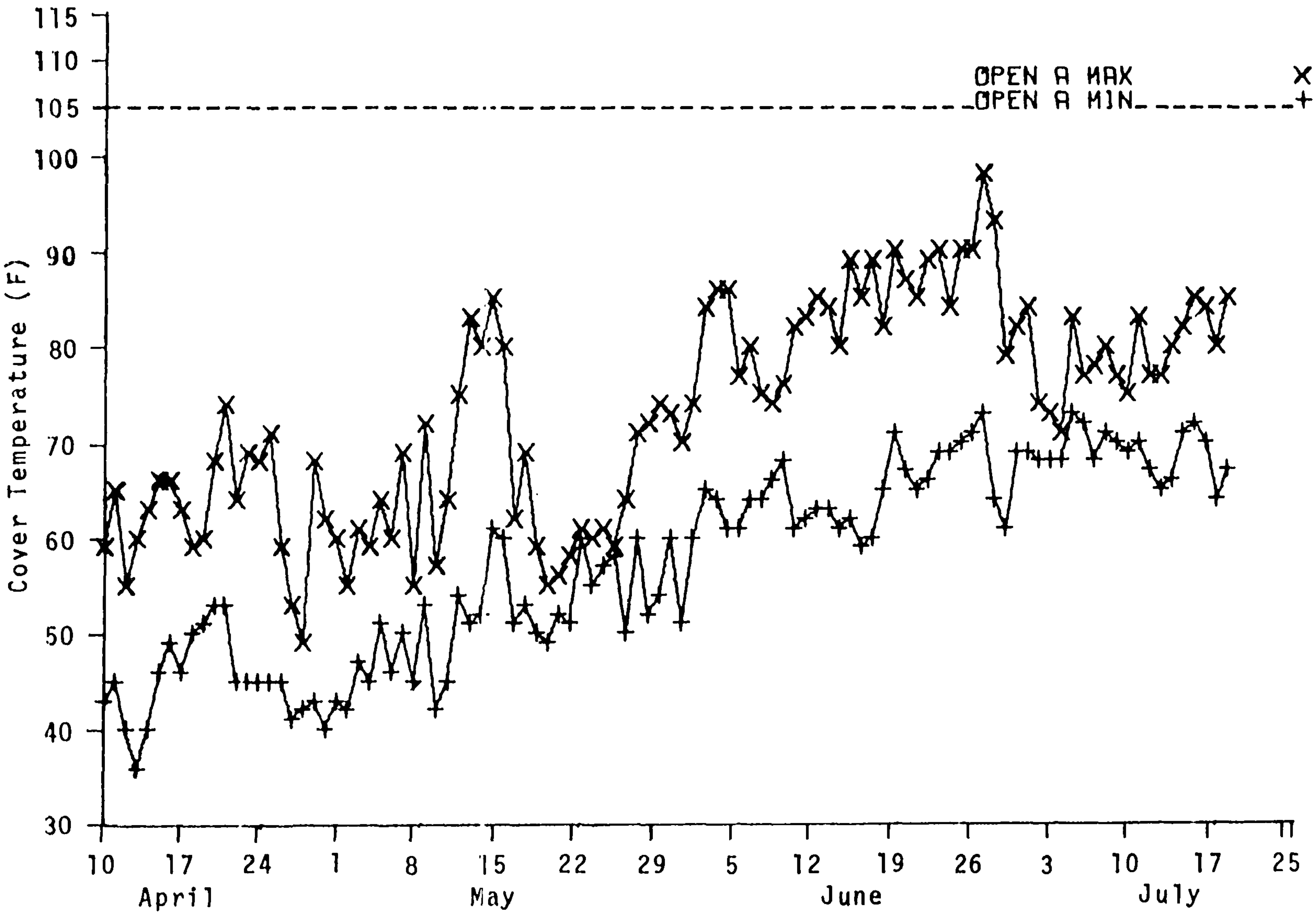
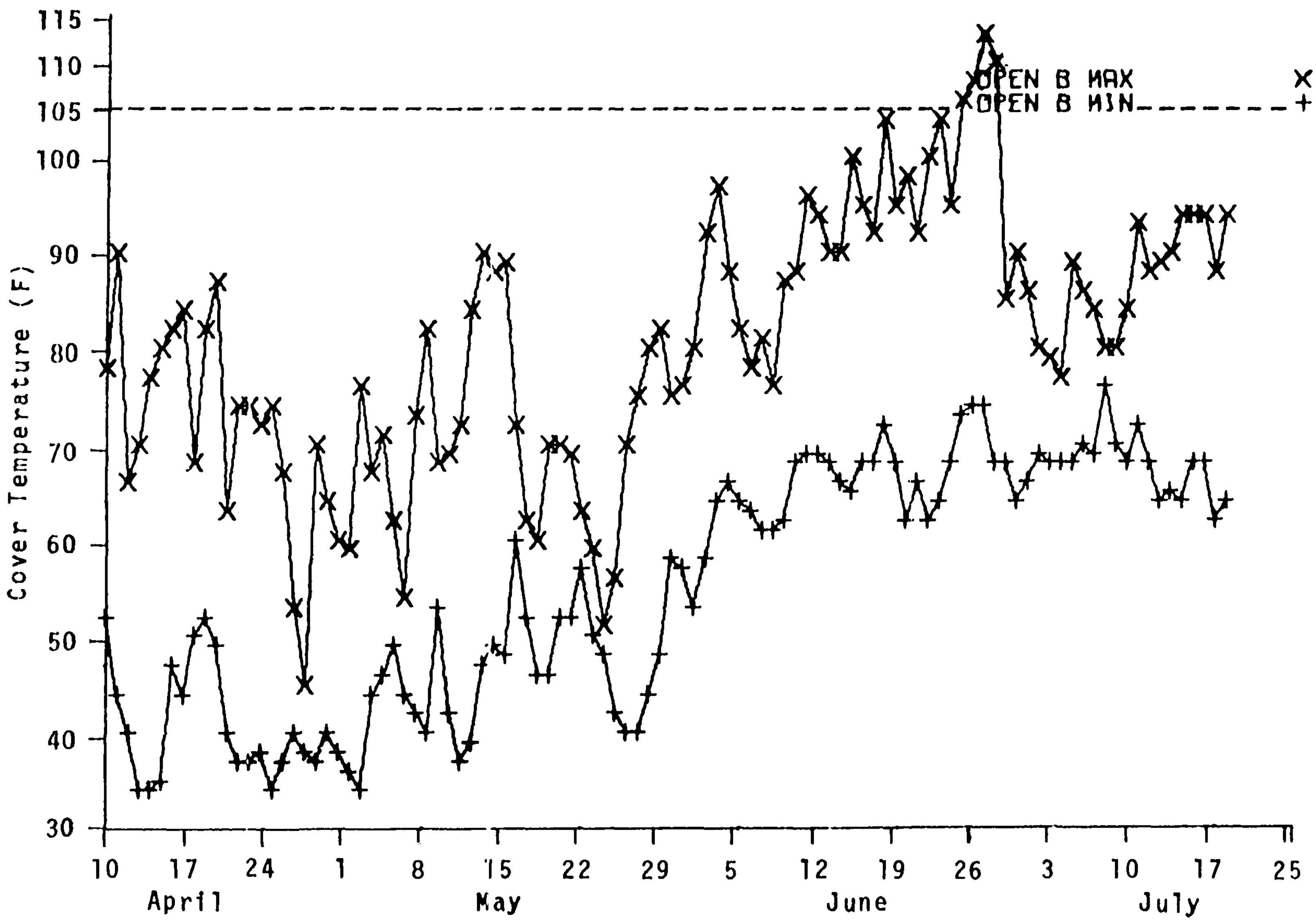

UNDER HUT MAX
UNDER HUT MIN
Cover Temperature (F)
115
110
105
100
90
80
70
60
50
40
30
10
17
24
April
1
8
15
22
29
May
5
12
19
26
June
3
10
17
25
July

Figure 14. Daily maximum and minimum temperatures in natural ground cover in sample A on the Hamilton County study area from 10 April to 20 July 1971.



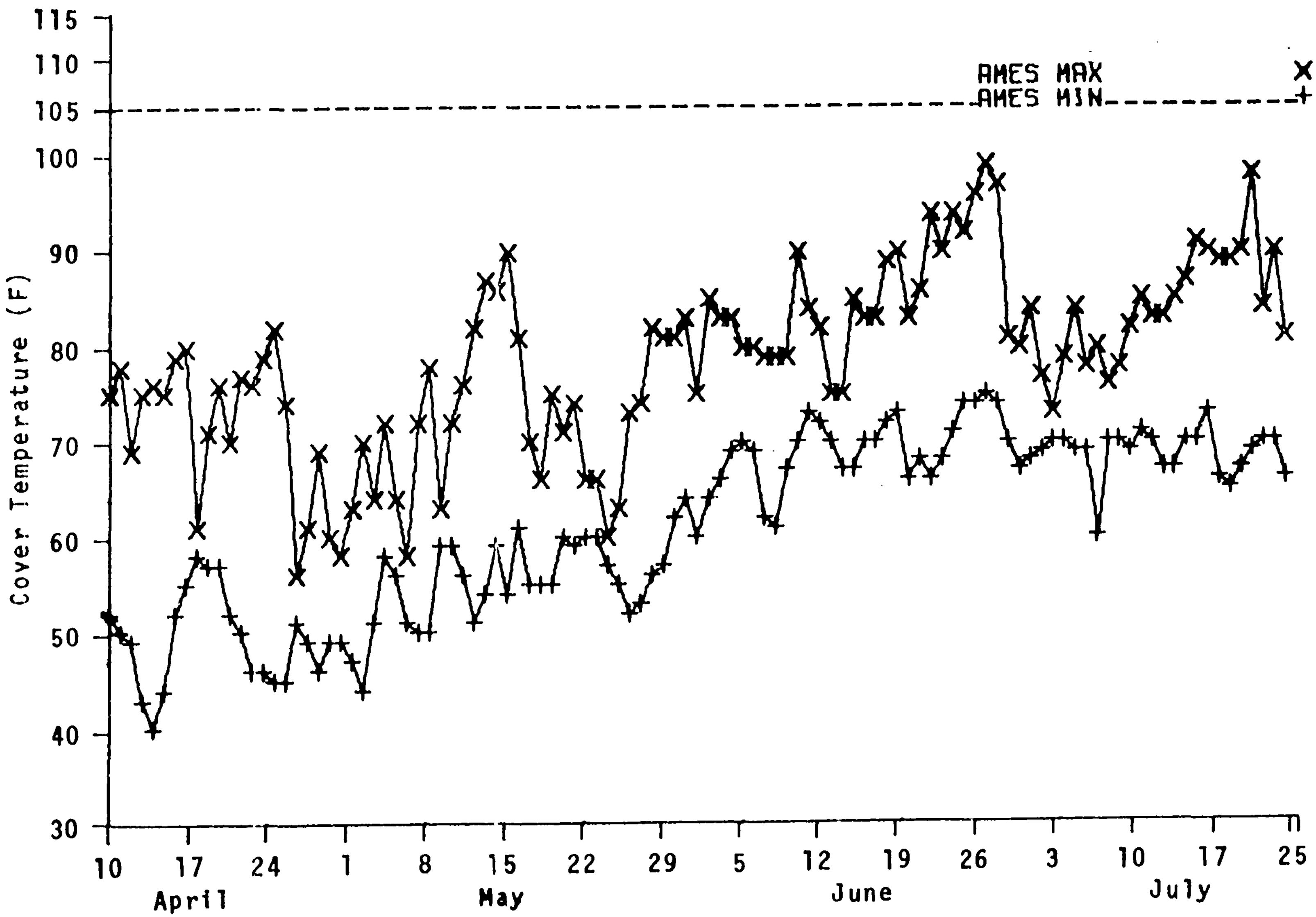
OPEN A MAX
OPEN A MIN
Cover Temperature (F)
115
110
105
100
90
80
70
60
50
40
30
10
17
24
1
8
15
22
29
5
12
19
26
3
10
17
25
April
May
June
July

Figure 15. Daily maximum and minimum temperatures in natural ground cover in sample B on the Hamilton County study area from 10 April to 20 July 1971.



OPEN B MAX
OPEN B MIN
Cover Temperature (F)
115
110
105
100
90
80
70
60
50
40
30
10
17
24
1
8
15
22
29
5
12
19
26
3
10
17
25
April
May
June
July

Figure 16. Daily maximum and minimum temperatures in natural ground cover at the Ames microclimate sampling station from 10 April to 25 July 1971.


Cover Temperature (F)
115
110
105
100
90
80
70
60
50
40
30
AMES MAX
AMES MIN
10
17
24
1
8
15
22
29
5
12
19
26
3
10
17
25
April
May
June
July

maxima recorded at the Ames microclimate station were 99, 97 and 96° F. The means for all 5 locations are given in Table 1, along with comparisons as determined by "t" tests. The results show that the highest mean maximum temperatures were recorded in open cover and the lowest in cover under the nesting structures.

The Hamilton County A probe in open cover registered lower mean maximum temperatures ($P < 0.01$) than did the Hamilton County B probe or the Ames probe, the latter two having been found to reflect no significant difference (Table 1). The explanation for this is believed to be that the A probe was by chance placed in a more protected position than the other two. As stated previously, all thermometers were operated under common conditions before and after field use to ascertain comparability. All of the probes were so placed as to receive little or no direct solar radiation, and would have had very conservative exposure compared with most unattended pheasant nests.

It may be noted that no significant difference resulted from the test for a difference between mean maximum temperatures recorded under the flat structure (70.3° F) and the mean maximum temperatures in nearby open cover (73.1° F) recorded by thermometer A (Table 1). The test statistic for this pair of means was 1.939 and the reference statistic for $P = 0.05$ with 202 degrees of freedom was 1.960, leaving the test statistic only 0.021 short of significance.

Means of minimum cover temperatures were less diverse than were means of maximum cover temperatures, significant differences being found in only 4 of 10 comparisons (Table 1). The highest mean minimum

Table 1. Comparisons of means of cover temperatures recorded under structures, in open cover near structures in Hamilton County and in open cover at Ames, Iowa, microclimate station, from 10 April thru 20 July, 1971

Source	Maximum means (°F)	Test results[a]	Minimum means (°F)	Test results[a]
Flat	70.3	NS	58.5	NS
Hut	68.4		57.7	
Ham. Co. open cover A	73.1	**	57.3	NS
Hut	68.4		57.7	
Ham. Co. open cover B	80.7	**	54.9	NS
Hut	68.4		57.7	
Ham. Co. open cover A	73.1	NS	57.3	NS
Flat	70.3		58.5	
Ham. Co. open cover B	80.7	**	54.9	*
Flat	70.3		58.5	
Ames open cover	78.1	**	60.5	*
Hut	68.4		57.7	
Ames open cover	78.1	**	60.5	NS
Flat	70.3		58.5	
Ham. Co. open cover B	80.7	**	54.9	NS
Ham. Co. open cover A	73.1		57.3	
Ames open cover	78.1	**	60.5	*
Ham. Co. open cover A	73.1		57.3	
Ham. Co. open cover B	80.7	NS	54.9	**
Ames open cover	78.1		60.5	

[a] N = 102, d.f. = 202 = 2(n - 1)
NS, $P > 0.05$
* $P < 0.05$
** $P < 0.01$

temperature was recorded at the Ames microclimate station, a possible explanation being that the vegetative cover was slightly higher and perhaps more dense there than the cover at the Hamilton County sampling station, resulting in less upward radiation and heat loss at night. There was no clear relationship demonstrated between heat loss under the structures as opposed to heat loss in open cover.

If 105° F is taken as the temperature where embryo mortality from heat becomes substantial, it would be of interest to ascertain the duration of temperatures above that level in nesting cover. Accordingly, the degree-minutes (sums of the number of minutes of each degree of temperature above 104° F on any one day) were calculated for the period 26 June to 29 June when the daily maximum temperatures recorded by thermometer B on the Hamilton County study area ranged from 106° F to 113° F in open cover. The results yielded daily degree-minute values of 80, 315, 370 and 1120, or a total of 1885 degree-minutes above 104° F in a period of 4 consecutive days.

Vapor pressure deficits

The drying capacity of the air, as measured by vapor pressure deficits, was found to exceed levels presumably favorable for pheasant embryo development in all cover situations where wet- and dry-bulb readings were taken (Figures 17, 18 and 19). At 101° F a minimum relative humidity level of 60 percent has been found to be necessary for successful pheasant embryo incubation (Romanoff 1934). This temperature-humidity combination converts to a saturation vapor pressure deficit value of 0.790 inches of

Figure 17. Vapor pressure deficits in natural ground cover, under a hut nesting structure and under a flat nesting structure on the Hamilton County study area between 10 April and 20 July in 1971. Entries at 0.0 vapor pressure deficit represent days when no data were recorded with the exceptions that 0.0 deficits were recorded in open cover on 7 June, under the flat structure on 27 May, 7 June and 9 July, and under the hut structure on 9 July.

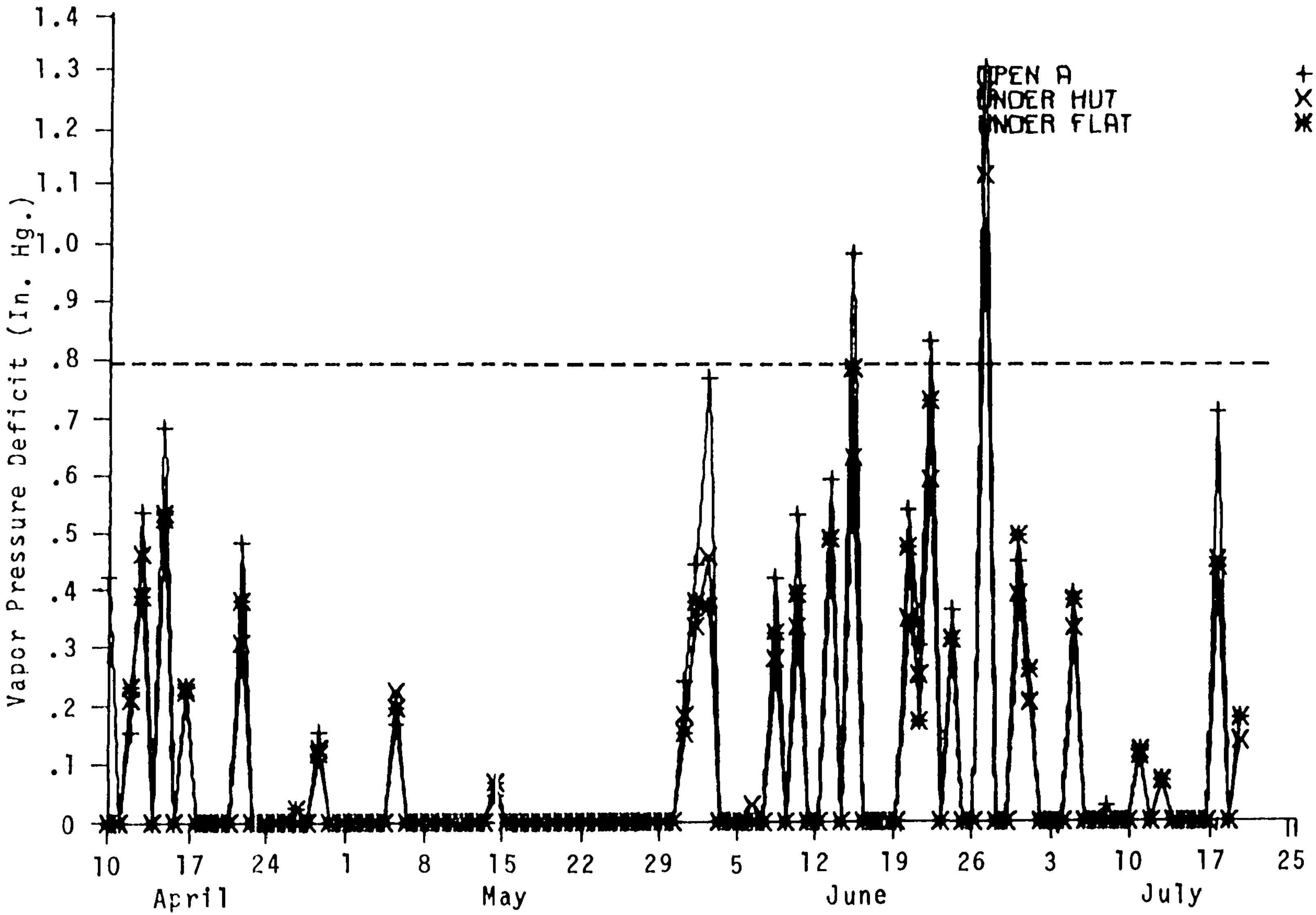

Vapor Pressure Deficit (In. Hg.)
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
OPEN A +
UNDER HUT X
UNDER FLAT ✱
10 17 24 1 8 15 22 29 5 12 19 26 3 10 17 25
April
May
June
July

Figure 18. Vapor pressure deficits in natural ground cover and in the air 3 feet above ground level on the Hamilton County study area between 10 April and 20 July in 1971. Entries at 0.0 vapor pressure deficit represent days when no data were recorded, with the exception that a 0.0 deficit was recorded in open cover on 7 June.

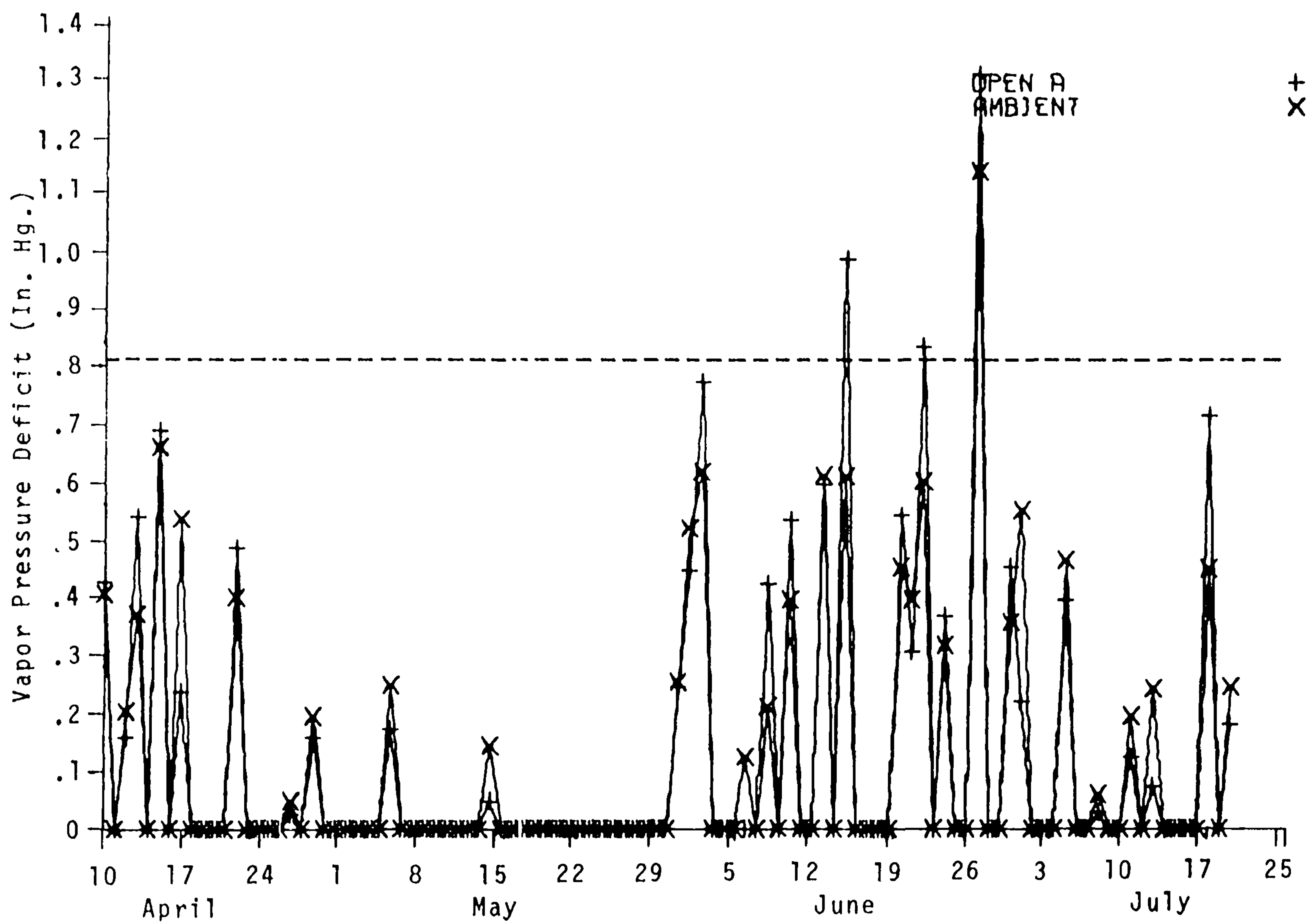
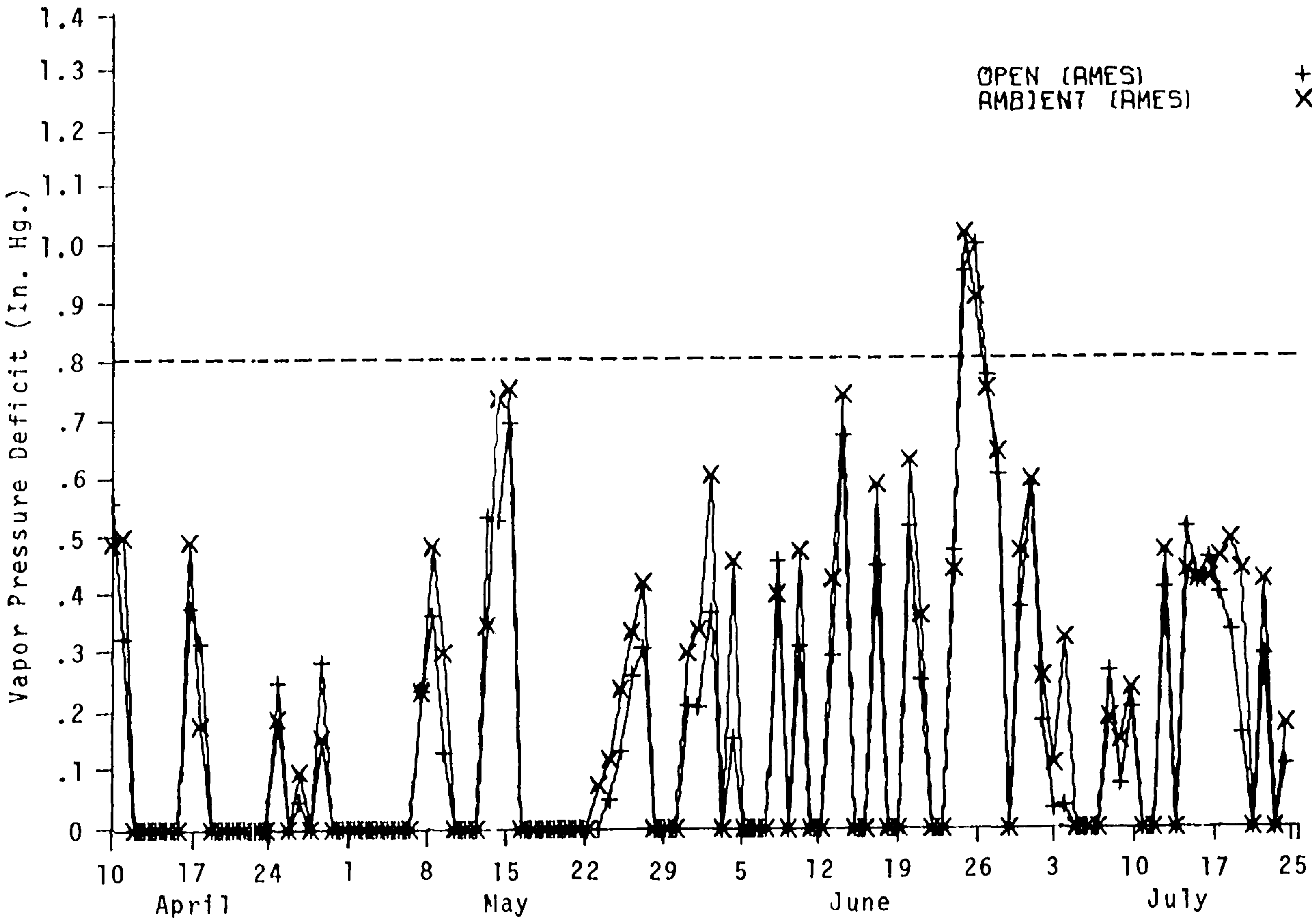

Vapor Pressure Deficit (In. Hg.)
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
10
17
24
1
8
15
22
29
5
12
19
26
3
10
17
25
April
May
June
July
OPEN A +
AMBIENT X

Figure 19. Vapor pressure deficits in natural ground cover and in the air 3 feet above ground level at the Ames microclimate sampling station between 10 April and 25 July, 1971. Entires at 0.0 vapor pressure deficit represent days when no data were recorded, with the exception that a 0.0 deficit was recorded in open cover on 24 May.


OPEN (AMES) +
AMBIENT (AMES) X
Vapor Pressure Deficit (In. Hg.)
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
10
17
24
1
8
15
22
29
5
12
19
26
3
10
17
25
April
May
June
July

mercury and is indicated by the dotted line in Figures 17, 18 and 19. Thus, any deficit value above about 0.800 could be considered detrimental to hatching success. Between 10 April and 20 July in 1971 these conditions occurred in the latter half of June only, and particularly during the extremely hot period of 26-29 June. The greatest deficits were recorded on 28 June on the Hamilton County study area. The readings on that date at 1415 hours were 1.302 in open cover, 1.264 under the flat structure, 1.118 under the hut structure and 1.134 in the air 3 feet above ground level. The maximum reading recorded in open cover at the Ames microclimate station was 1.003 the preceding day at 1535 hours.

A total of 30 readings were made on the Hamilton County study area and 51 at the Ames microclimate station during 1971. Many of the Hamilton County readings were made in the forenoon, well before the daily mid-afternoon vapor pressure deficit peak. Even so, the mean deficit in open cover on the Hamilton County study area (0.401 in. Hg.) was greater than in the open cover at the Ames microclimate station (0.356 in. Hg.). Statistical tests for differences between these values were not appropriate, however, because of the disparity in time of day and of differences between days when readings were made at the two locations.

No significant differences ($P > 0.05$) were found between mean deficits recorded under the hut and the flat structures, or between the ambient and the open cover readings in Hamilton County (Table 2). The Hamilton County open cover mean deficit was greater ($P < 0.01$) than the mean deficits under either the hut or flat structures. At the Ames

Table 2. Comparisons of means of vapor pressure deficits recorded under structures, in open cover near structures, and at 3 feet above ground level in Hamilton County and in open cover and 3 feet above ground level at the Ames, Iowa, microclimate station between 10 April and 25 July, 1971

Source	Vapor pressure deficit means (In. Hg.)	Test results[a]	Degrees of freedom (n-1)
Flat	0.333	NS	29
Hut	0.310		
Ham. Co. open cover	0.401	**	29
Hut	0.310		
Ham. Co. open cover	0.401	**	29
Flat	0.333		
Ham. Co. open cover	0.401	NS	29
Ham. Co. ambient	0.386		
Ames ambient	0.421	**	50
Ames open cover	0.356		

[a]NS, P > 0.0
** P < 0.0

microclimate station the mean ambient deficit (0.421) was higher ($P < 0.01$) than in the open cover (0.356).

Soil temperatures

Soil temperature records for 1969, 1970 and 1971 published by the Environmental Data Service were evaluated to establish whether any substantial differences between years occurred in temperatures near the surface of the ground. Though temperatures reached in bare soil at a depth of 1-inch cannot necessarily be considered as equivalent to temperatures in vegetative cover at ground level, they will reflect changes in temperature patterns between years and serve as an index accordingly. Prior to undertaking this evaluation it was ascertained that daily soil temperatures were very highly correlated ($P < 0.0001$) with daily maximum air temperatures ($r = 0.916$), daily maximum cover temperatures at the Ames microclimate station ($r = 0.857$), and the daily maximum cover temperatures recorded on the Hamilton County study area by thermometers A ($r = 0.708$) and B ($r = 0.834$).

Maximum soil temperatures recorded during the incubation season of 15 April thru 25 July in 1971 were 112° F (28 June), 108° F (23 June) and 105° F (29 June). By comparison, in 1970, the maxima were 106° F (2 July), 105° F (14 July) and 104° F (14 June), and in 1969 highs of only 102° F (16 July) and 98° F (22,24,25 July) were recorded. It should be noted that the soil temperatures reported here were recorded at 1700 hours, C.S.T., whereas daily maximum soil temperatures at a depth of 1 inch would normally occur between 1200 and 1400 hours (Elford and Shaw 1960:4).

During the period of 1 March thru 31 August, considered here as the entire pheasant reproductive season, mean temperatures became increasingly higher from 1969 thru 1971 (Table 3). Significant differences (P < 0.05) as determined by "t" tests for differences between means, were found between 1969 and 1970, and between 1969 and 1971, with 1969 being the cooler of the two years in both cases. No significant difference existed between 1970 and 1971 (P > 0.05), although the 1971 mean was 1.5 F higher.

Comparisons of pre-nesting periods (1 March to 10 May, Figure 20), pre-incubation periods (15 April to 30 June), incubation periods (15 April to 25 July, Figure 21), and rearing periods (19 May to 31 August, Figure 22), revealed the same pattern, warmer in 1970 and 1971 than in 1969 (Table 3). One notable exception did occur, however, in the 3-week period, 20 April to 10 May, immediately preceeding the nesting season (Figure 23). (Mean temperatures from 20 April to 10 May in 1970 were warmer (P < 0.05) than both 1969 (by 8.4° F) and 1971 (by 5.1° F) Table 3).) Temperatures during this period have been found to be highly correlated with pheasant population trends in Wisconsin by Wagner et al. (1965:78), in that warmer temperatures there are associated with years of high pheasant reproductive success.

Precipitation

Total precipitation during the period 1 March to 31 August decreased from a high of 27 inches in 1969, to 19 inches in 1970, to 14 inches in 1971 (Table 4). Normal for that period is 19.71 inches. The distribution

Table 3. Soil temperature means (at a depth of 1 inch) at Ames, Iowa during selected periods of the pheasant reproductive season in 1969, 1970 and 1971

Biological period	Dates	Soil temperature means			Comparisons ($P < 0.05$)		
		1969	1970	1971	69 vs 70	69 vs 71	70 vs 71
Reproductive season	1 Mar-31 Aug (d.f. = 366)	67.9	70.9	72.4	70 > 69	71 > 69	NS
Pre-nesting	1 Mar-10 May (d.f. = 140)	46.0	48.2	48.9	70 > 69	71 > 69	NS
Immediate pre-nesting	20 Apr-10 May (d.f. = 40)	62.0	68.4	63.3	70 > 69	NS	70 > 71
Pre-incubation	15 Apr-30 Jun (d.f. = 152)	70.0	76.0	77.0	70 > 69	71 > 69	NS
Incubation	15 Apr-25 Jul (d.f. = 202)	74.0	79.7	79.9	70 > 69	71 > 69	NS
Rearing	10 May-31 Aug (d.f. = 224)	81.4	85.1	87.0	70 > 69	71 > 69	NS

Figure 20. Temperatures of bare soil, recorded at a depth of 1-inch at 1700 hours, from 1 March to 10 May (pre-nesting period) in 1969, 1970 and 1971, near Ames, Iowa.

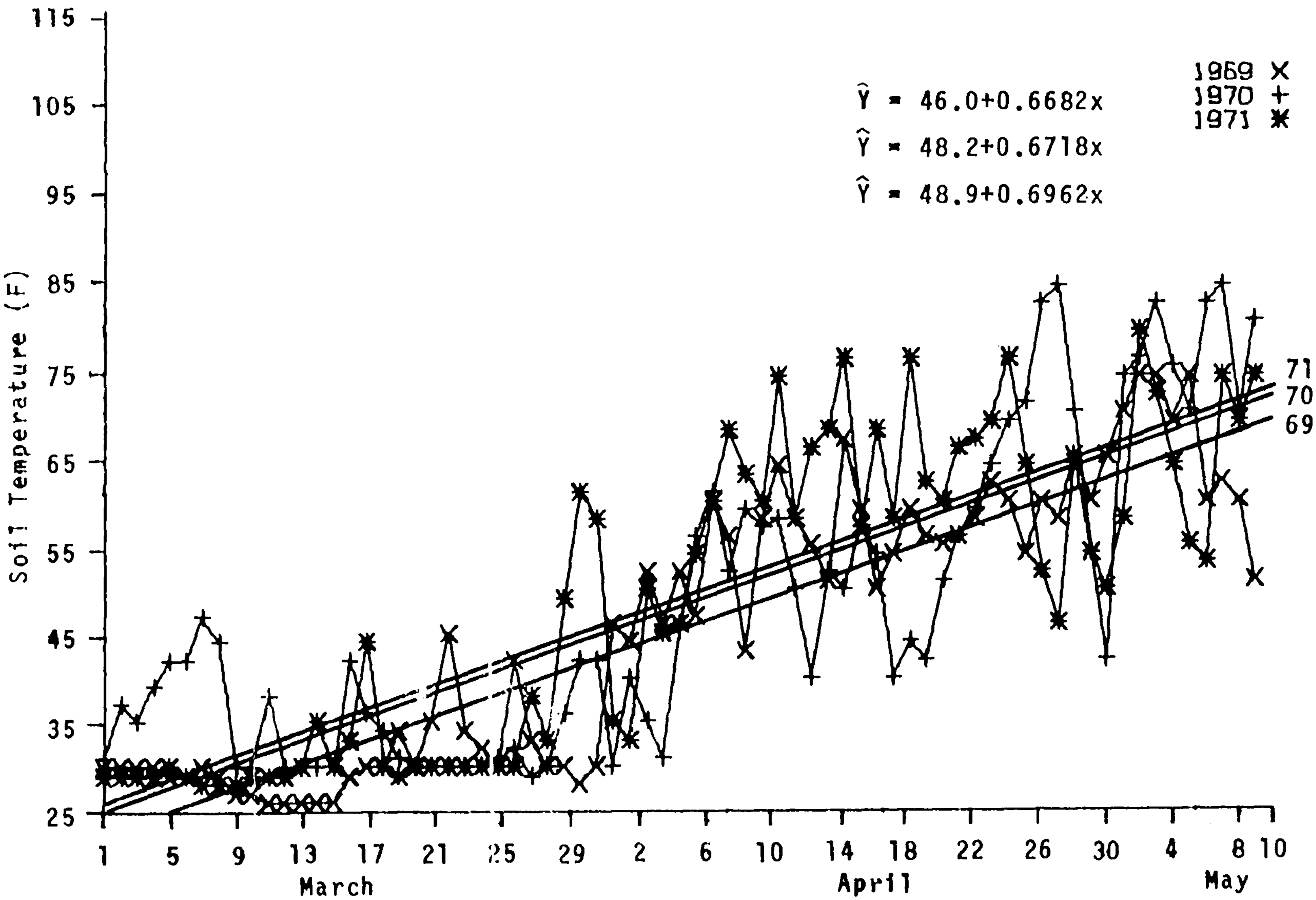
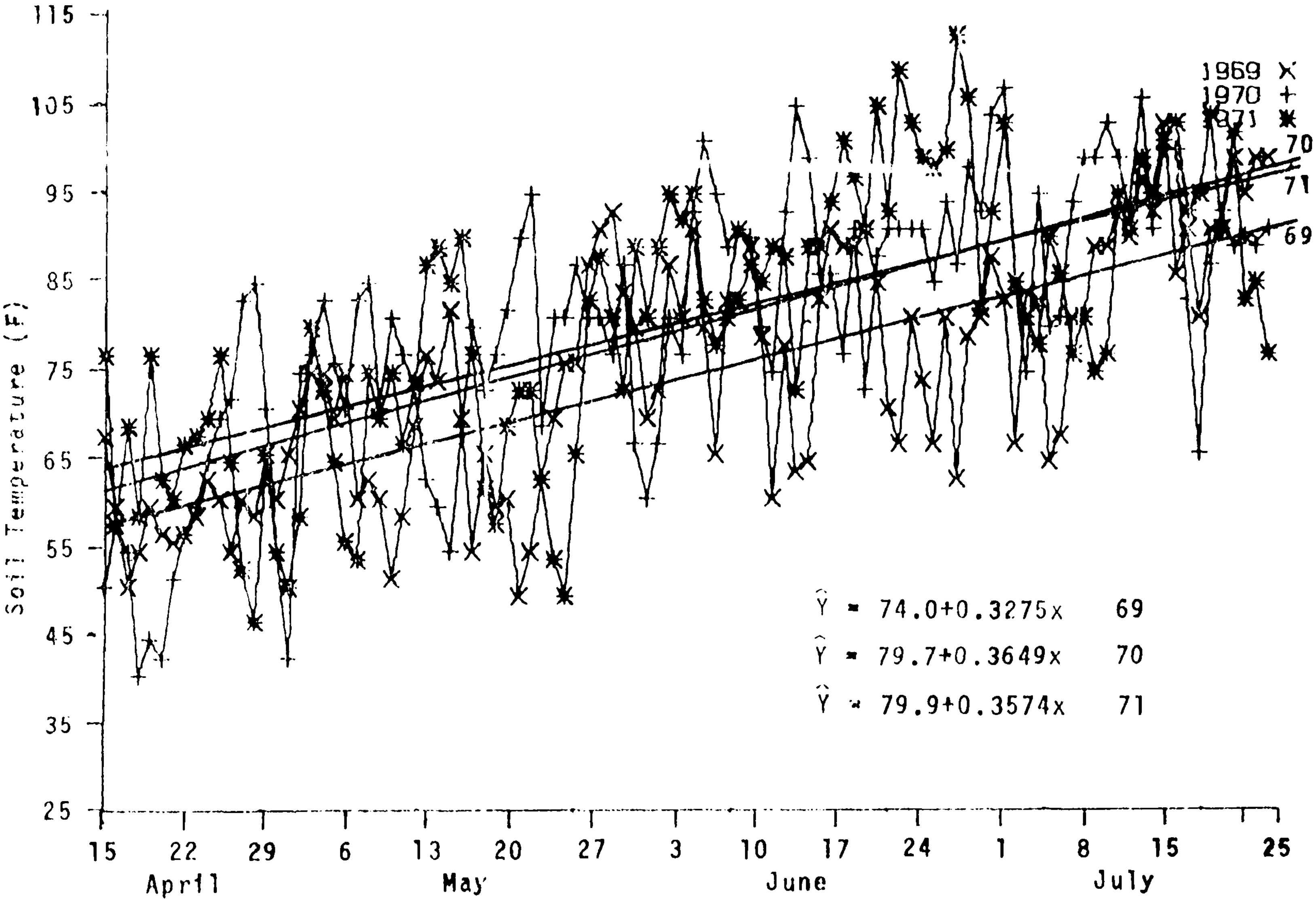

Soil Temperature (F)
115
105
95
85
75
65
55
45
35
25
Ŷ = 46.0+0.6682x
Ŷ = 48.2+0.6718x
Ŷ = 48.9+0.6962x
1969 X
1970 +
1971 ✱
71
70
69
1 5 9 13 17 21 25 29
March
2 6 10 14 18 22 26 30
April
4 8 10
May

Figure 21. Temperatures of bare soil, recorded at a depth of 1-inch at 1700 hours, from 15 April to 25 July (incubation period) in 1969, 1970 and 1971, near Ames, Iowa.



Soil Temperature (F)
115
105
95
85
75
65
55
45
35
25
15
22
29
6
13
20
27
3
10
17
24
1
8
15
25
April
May
June
July
1969 X
1970 +
1971 ✱
70
71
69
$\hat{Y}$ = 74.0+0.3275x 69
$\hat{Y}$ = 79.7+0.3649x 70
$\hat{Y}$ = 79.9+0.3574x 71

Figure 22. Temperatures of bare soil, recorded at a depth of 1-inch at 1700 hours, from 10 May to 31 August (rearing period) in 1969, 1970 and 1971, near Ames, Iowa.

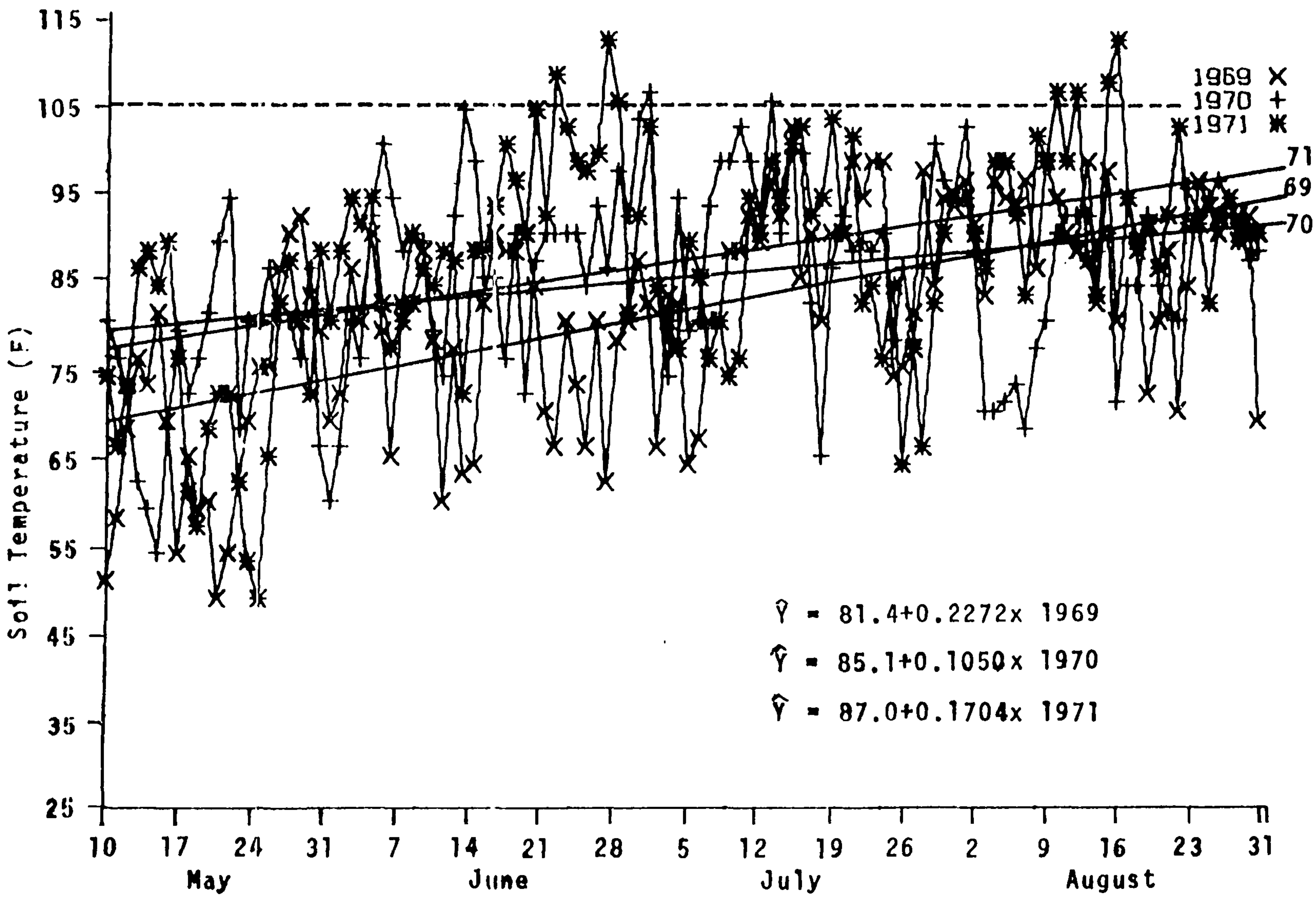

Soil Temperature (F)
115
105
95
85
75
65
55
45
35
25
10
17
24
31
7
14
21
28
5
12
19
26
2
9
16
23
31
May
June
July
August
1969 X
1970 +
1971 ✱
71
69
70
Ŷ = 81.4+0.2272x 1969
Ŷ = 85.1+0.1050x 1970
Ŷ = 87.0+0.1704x 1971

Figure 23. Temperatures of bare soil, recorded at a depth of 1-inch at 1700 hours, from 20 April to 10 May (immediate pre-nesting period) in 1969, 1970 and 1971, near Ames, Iowa.

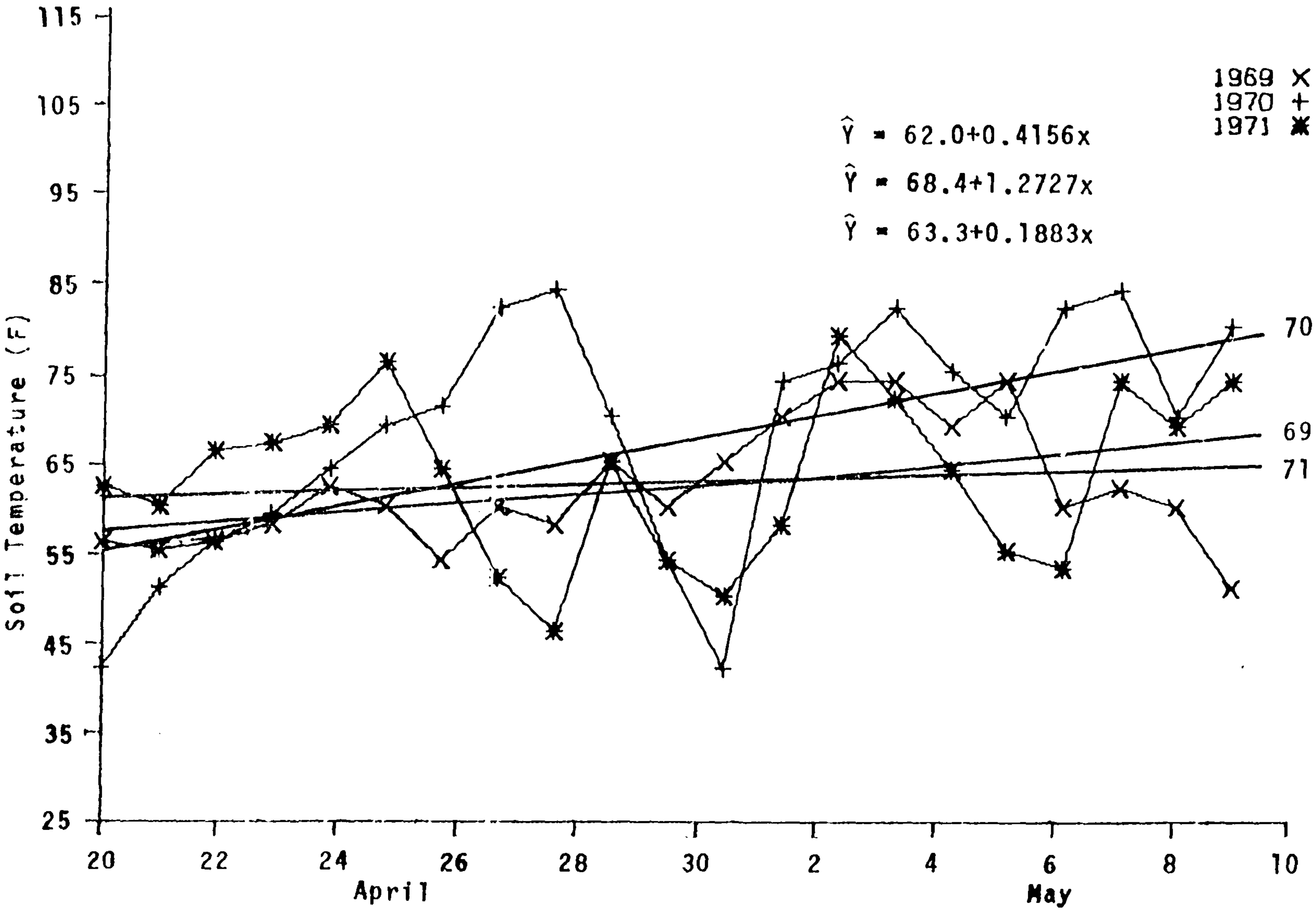

1969 ×
1970 +
1971 ✱
$\hat{Y}$ = 62.0+0.4156x
$\hat{Y}$ = 68.4+1.2727x
$\hat{Y}$ = 63.3+0.1883x
70
69
71
Soil Temperature (F)
115
105
95
85
75
65
55
45
35
25
20
22
24
26
28
30
2
4
6
8
10
April
May

Table 4. Monthly precipitation from March through August at Jewell, Iowa in 1969, 1970 and 1971

	Inches of precipitation			
Month	1969	1970	1971	Normal[a]
March	0.97	1.97	0.74	1.66
April	3.57	2.30	0.80	2.41
May	4.72	2.09	2.97	3.87
June	6.71	3.38	4.38[b]	4.90
July	8.72	5.36	4.96	3.47
August	2.67	3.96	0.46	3.40
TOTALS	27.36	19.06	14.31	19.71

[a]Normal data are for Webster City, Iowa.

[b]June 1971 data are for Ames, Iowa.

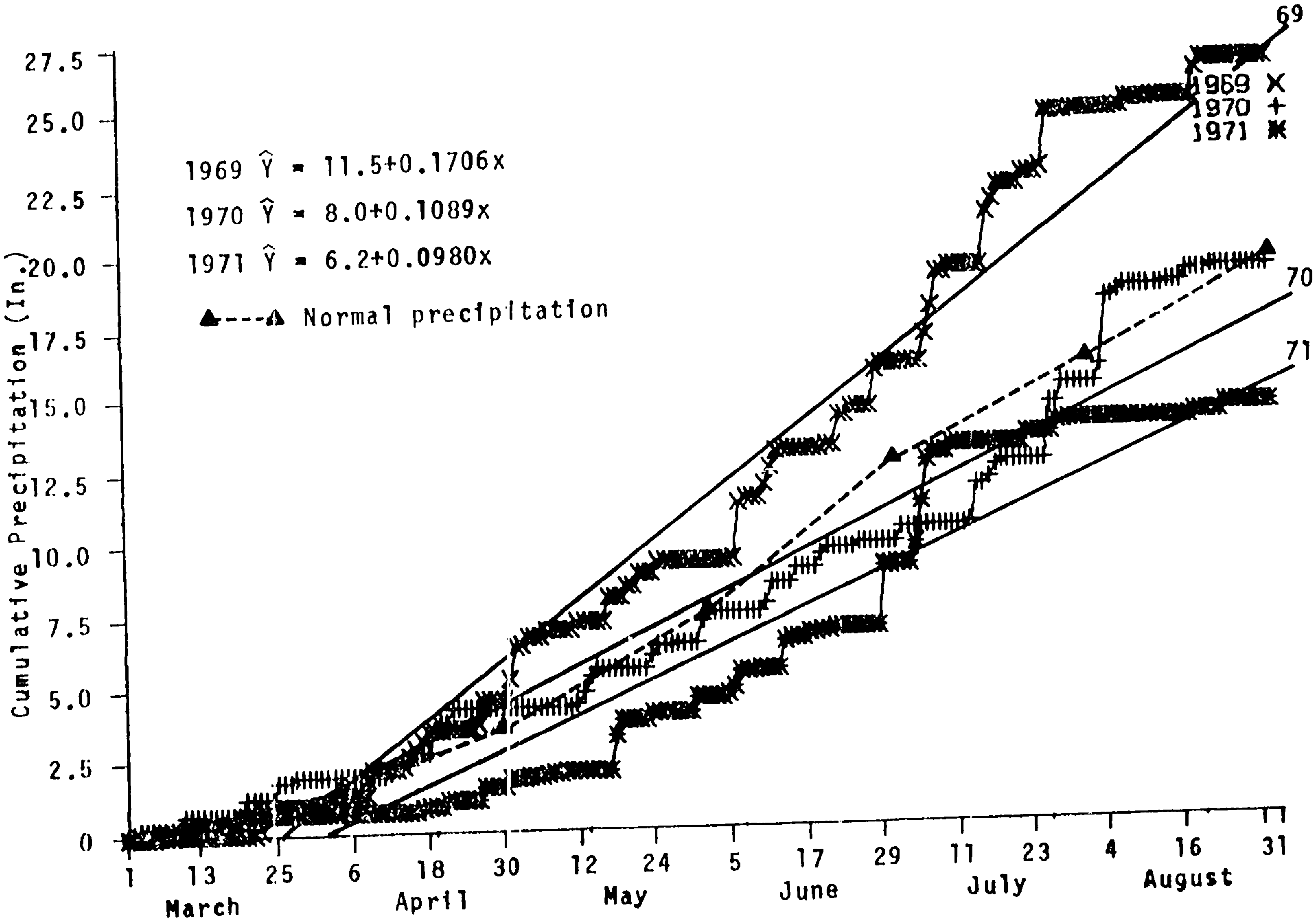
of rainfall, as expressed by inches cumulated after March 1, also differed substantially between the 3 years (Figure 24). Especially notable was the excess above normal after late April and again after early June that occurred in 1969, and the deficiency that began in late March and continued to late June in 1971. In contrast, the 1970 distribution remained very close to normal from 1 March through about mid-June, then returned to near normal after mid-July.

Tests for differences in precipitation between years within biological periods revealed few differences as measured by mean daily rainfall (Table 5). Over the entire season, 1 March to 31 August, however, 1969 had higher daily means than both 1970 and 1971, and 1970 had a higher daily mean than 1971 ($P < 0.05$).

Temperature and moisture values in a pheasant nest

One of the basic questions regarding the microclimate of pheasant nests is whether the principal source of atmospheric moisture surrounding the eggs emanates from the hen, the soil, transpiring plants, the air or some combination of these sources. On 2 June 1971 a hen was flushed at 1241 hours (C.S.T.) from a nest containing nine eggs and located at the bottom of a roadside ditch in knee-high brome and bluegrass. Accessibility to field equipment made it possible to place a hand-aspirated psychrometer in the nest bowl within 3 minutes of the time the hen flushed. A series of wet- and dry-bulb temperature readings were then taken with the intent of obtaining some indication of whether the level of atmospheric moisture surrounding the eggs declined with time

Figure 24. Cumulative precipitation from 1 March to 31 August in 1969, 1970 and 1971 at Jewell, Iowa.



Cumulative Precipitation (In.)
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0
1969 $\hat{Y}$ = 11.5+0.1706x
1970 $\hat{Y}$ = 8.0+0.1089x
1971 $\hat{Y}$ = 6.2+0.0980x
Normal precipitation
1969 X
1970 +
1971 ✱
69
70
71
1
13
25
6
18
30
12
24
5
17
29
11
23
4
16
31
March
April
May
June
July
August

Table 5. Daily precipitation means at Jewell, Iowa during selected periods of the pheasant reproductive season in 1969, 1970 and 1971

Biological period	Dates	Daily precipitation means (in.)			Comparisons ($P < 0.05$)		
		1969	1970	1971	69 vs 70	69 vs 71	70 vs 71
Reproductive season	1 Mar-31 Aug (d.f. = 366)	0.14	0.10	0.08	69 > 70	69 > 71	70 > 71
Pre-nesting	1 Mar-10 May (d.f. = 140)	0.10	0.06	0.03	NS	69 > 71	NS
Immediate pre-nesting	20 Apr-10 May (d.f. = 40)	0.16	0.03	0.05	69 > 70	NS	NS
Pre-incubation	15 Apr-30 Jun (d.f. = 152)	0.18	0.10	0.11	NS	NS	NS
Incubation	15 Apr-25 Jul (d.f. = 202)	0.20	0.10	0.12	69 > 70	NS	NS
Rearing	10 May-31 Aug (d.f. = 224)	0.17	0.13	0.11	NS	NS	NS

after the departure of the hen. If this occurred it would suggest that the hen is a primary source of moisture.

Results of the psychrometer readings, taken alternately in the nest and at ground level in cover 12 inches from the nest, are shown in Table 6. The drying capacity of the air in the nest bowl was greater than the drying capacity in the cover 12 inches from the nest in each of six pairs of readings. A "t" test showed the mean vapor pressure deficit values for the nest samples to be significantly greater than for the cover samples ($P < 0.05$). The drying capacity of the air in the nest averaged 15 percent greater than in the adjacent cover. The relative humidity in the nest ranged from 48 to 54 percent, in natural cover from 50 to 57 percent and in the air from 50 to 58 percent. Ambient temperatures increased slightly during the hour after the hen was flushed. The slight depression in temperature in the nest 23 minutes after the hen was flushed (Table 6) was caused by a passing cloud.

Recognizing that these data represent only one instance, several inferences might be drawn from the resulting pattern of microclimate values. First, the level of atmospheric moisture surrounding the eggs did decline with time after the departure of the hen. However, the immediate and longer term drying capacity changes in the nest essentially paralleled those in the adjacent natural cover (Figure 25) and seemed to be independent of any carryover effect of the hen. It should be noted that this hen was only laying (as evidenced by opening and examining 1 egg and later deposits in the nest of 5 more eggs) so the length of time that she was on the nest prior to being flushed is uncertain.

Table 6. Microclimate parameters of an unoccupied pheasant nest and adjacent cover on 2 June 1971 in Hamilton County, Iowa

Location	Minutes after hen flushed	Dry bulb temp. (° F)	Saturation vapor pressure deficit (in. Hg.)	Nest deficit minus natural cover deficit	Percent greater drying capacity in nest than in natural cover
Nest	3	83	0.580	0.069	13.5
Nest	13	85	0.570	0.057	11.1
Nest	23	83	0.547	0.045	9.0
Nest	35	88	0.648	0.101	18.5
Nest	46	87	0.673	0.151	28.9
Nest	56	88	0.608	0.061	11.2
12" from nest	7	80	0.511		
12" from nest	16	82	0.513		
12" from nest	26	83	0.502		
12" from nest	39	83	0.547		
12" from nest	50	85	0.522		
12" from nest	60	83	0.547		
Air at 3 feet	10	71	0.316		
Air at 3 feet	33	74	0.385		
Air at 3 feet	54	74	0.419		

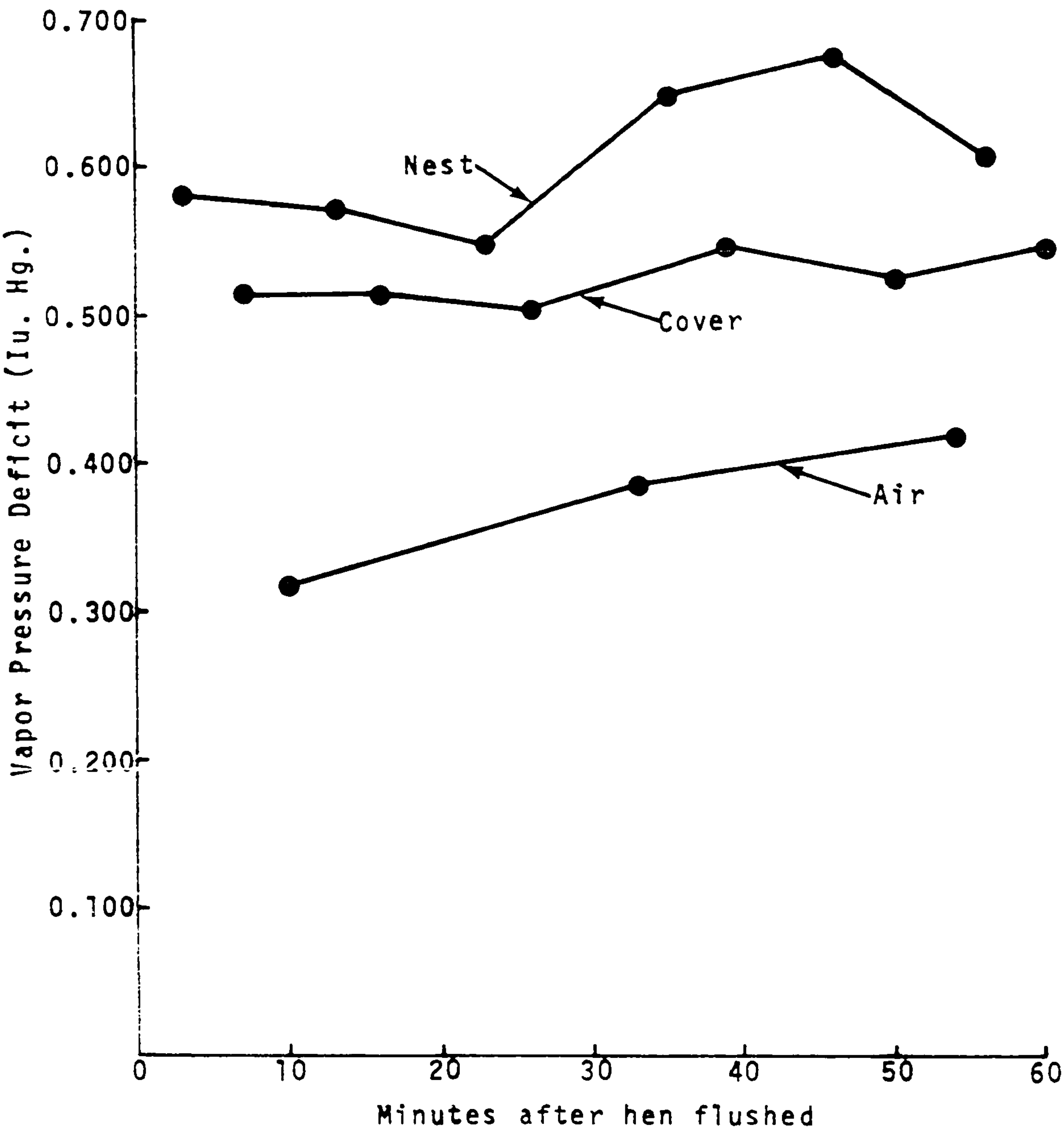


Figure 25. Drying capacity of ambient air, an unoccupied pheasant nest and adjacent cover in Hamilton County, Iowa, on 2 June 1971.

Second, the nest microclimate was not as favorable to incubation in the absence of the hen as was adjacent natural cover in that the nest was warmer (with the potential of becoming critically warm) and drier than both the adjacent cover and the ambient air. The cause of the differences between the two ground locations was the direct overhead exposure of the nest. This condition implies a third point, and that is the value of overstory (of either broad-leaved plants or very high grass) in pheasant nesting cover in tempering microclimate extremes in an unoccupied nest.

Population Levels

Summer roadside survey results showed that pheasant population levels on the study area were about equal in 1969 and 1971, but were significantly higher than either year in 1970. The results of weekly counts are summarized in Table 7 and annual summaries are given in Table 8. The locations of all broods seen during counts in each of the 3 years of the study are shown in Figure 10 (page 26).

The number of hen pheasants seen during the course of the summer surveys was 101, 122 and 124, 1969 thru 1971. Chi-square tests for the null hypothysis that the number of hens observed (all hen observations beginning with the survey when the first brood was seen) in 1971 was no different than the number observed in 1969, did not yield a test value significant at the 0.05 level of probability ($P > 0.10$). The 1969-1970 and 1970-1971 differences were not tested since they were of a lesser magnitude than the 1969-1971 difference. Thus, it was concluded that

Table 7. Summary of weekly roadside pheasant counts, Hamilton County study area, 1969, 1970 and 1971

Date	Males	Females	Chicks	Number broods	Total pheasants
			1969		
30 June	12	11	0	0	23
2 July	--	--	--	--	--
11 July	12	11	12	1	35
16 July	--	--	--	--	--
24 July	12	14	18	4	44
1 Aug.	9	16	28	6	53
6 Aug.	2	4	5	3	11[a]
13 Aug.	4	8	26	8	38[a]
22 Aug.	10	20	61	17	91
29 Aug.	1	4	40	8	45[a]
5 Sept.	4	10	64	12	78
11 Sept.	9	14	77	15	100
Totals	75	112	331	74	518
			1970		
18 June	6	8	0	0	14[a]
24 June	--	--	--	--	--
1 July	--	--	--	--	--
8 July	6	7	30	4	43
16 July	10	18	34	5	62
22 July	16	16	37	10	69
30 July	9	16	60	13	85
6 Aug.	8	15	69	11	92
13 Aug.	8	14	75	14	97
19 Aug.	4	19	103	20	126
26 Aug.	3	10	96	16	109
2 Sept.	2	7	80	13	89[a]
Totals	72	130	584	106	786

[a]Very light dewfall.

Table 7. Continued

Date	Males	Females	Chicks	Number broods	Total pheasants
			1971		
23 June	4	6	0	0	10[a]
1 July	14	12	0	0	26
9 July	22	16	8	1	46
14 July	10	5	0	0	15
21 July	10	17	41	5	68
29 July	14	23	52	8	89
5 Aug.	10	14	49	9	73
11 Aug.	3	9	28	6	40
18 Aug.	1	20	99	18	120
25 Aug.	4	10	46	10	60
2 Sept.	6	10	45	10	61
Totals	98	142	368	67	608

Table 8. Annual summaries of nine roadside pheasant counts, Hamilton County study area, 1969, 1970 and 1971

Observations	1969	1970	1971
Total hens (beginning with survey when first brood was seen)	101	122	124
Total chicks	331	584	368
Individual chicks[a]	284	504	289
Number broods	74	106	67
Individual broods[a]	60	88	51
Chicks per brood[a]	4.73	5.73	5.66
Mode of brood sizes	3	4	3
Chicks per hen[b]	4.26 (196/46)	6.51 (423/65)	4.24 (267/63)
Percent hens with broods[b]	67 (31/46)	80 (52/65)	67 (42/63)
Broods per survey mile (279 miles)	0.27	0.38	0.24

[a]After duplicate observations were deleted.

[b]Five Surveys, 5 Aug. - 5 Sept.

the number of hen pheasants on the study area during the summer was substantially the same in all three years of the study. It is further inferred that the number of hens in the breeding population over the three years was approximately the same from year to year, though the number in 1969 may have been slightly less than in 1970 and 1971.

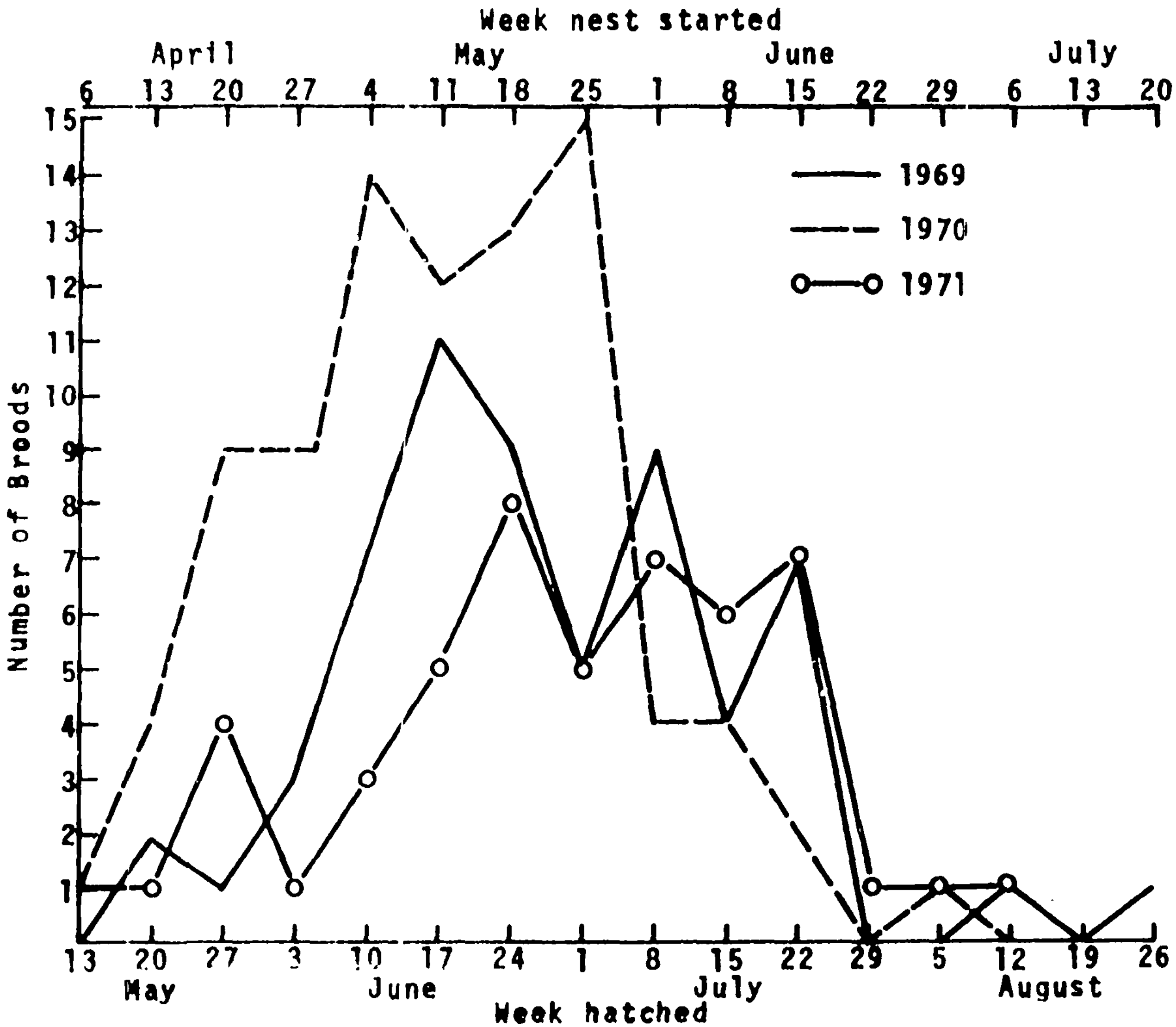
The number of chicks observed (after duplicate observations were deleted) over the three years of the study was 284, 504 and 289 in 1969 thru 1971. It was determined from chi-square tests that the number seen in 1970 was greater than in 1969 ($P < 0.005$) and 1971 ($P < 0.005$) but the numbers seen in 1969 and 1971 were not significantly different ($P > 0.75$). As would be expected, the same pattern held for the number of broods observed. The number of individual broods seen in 1969 was 60, in 1970 was 88 and in 1971 was 51. More were seen in 1970 than in 1969 ($P < 0.025$) or in 1971 ($P < 0.005$) but there was no significant difference between 1969 and 1971 ($P > 0.25$).

Differences between years in ratios of chicks per hen were examined as indicators of reproductive success. Observations made between 5 August and 5 September only were used (Table 7, pages 73, 74) because of the greater maturity and observability of broods that late in the summer. The ratios in 1969 (4.26 chicks per hen) and in 1971 (4.24 chicks per hen) were judged by inspection to be no different. The 1970 ratio (6.51 chicks per hen) was found significantly higher than either 1969 ($P < 0.005$) or 1971 ($P < 0.005$).

The percentage of hens with broods in each year was also examined as an index of reproductive success. In both 1969 and 1971, 67 percent of all hens seen during the five surveys conducted between 5 August and 5 September were accompanied by broods, whereas in 1970, 80 percent were with broods (Table 8, page 75). Results of tests for the equality of two proportions (Freund et al. 1960:28) for the null hypothesis that the proportion of hens observed with broods in 1970 was no different than the proportion observed in 1969 yielded a test statistic (1.516) with a probability of 0.0648. In the judgment of the investigator this probability is sufficiently small to consider the 13 percent difference between the two years as a significant difference. The test for differences between the years 1970 and 1971 yielded a test statistic (1.716) with a probability of 0.0433. Hence, it was concluded that a higher proportion of hens in the population reared broods in 1970 than did hens in either 1969 or 1971.

Progression of the nesting season differed substantially during the 3 years of the study (Figure 26). The earliest successful nests were started the week of April 6 in 1970 and 1971 and the week of April 13 in 1969. The 1970 season progressed rapidly right from the start, the 1969 season started slowly but then progressed rapidly, but the 1971 season started slowly, regressed and then progressed at a slower rate than either 1969 or 1970. The 1970 season reached dual peaks 3 weeks apart, 4 May and 25 May, and the 1969 season reached dual peaks 3 weeks apart, but 1 week later. The 1971 season did not reach even one distinct peak and certainly was not bi-modal. Initiation of nests was virtually complete by 1 June in 1970, but not until about 15 June in 1969 and 1971. Nest initiation was 55 percent complete by 11 May in 1970, 18 May in 1969

Figure 26. Week nest started and week of hatch of broods observed on Hamilton County study area in 1969, 1970 and 1971.


Week nest started
April
May
June
July
6 13 20 27 4 11 18 25 1 8 15 22 29 6 13 20
1969
1970
1971
Number of Broods
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
13 20 27 3 10 17 24 1 8 15 22 29 5 12 19 26
May
June
July
August
Week hatched

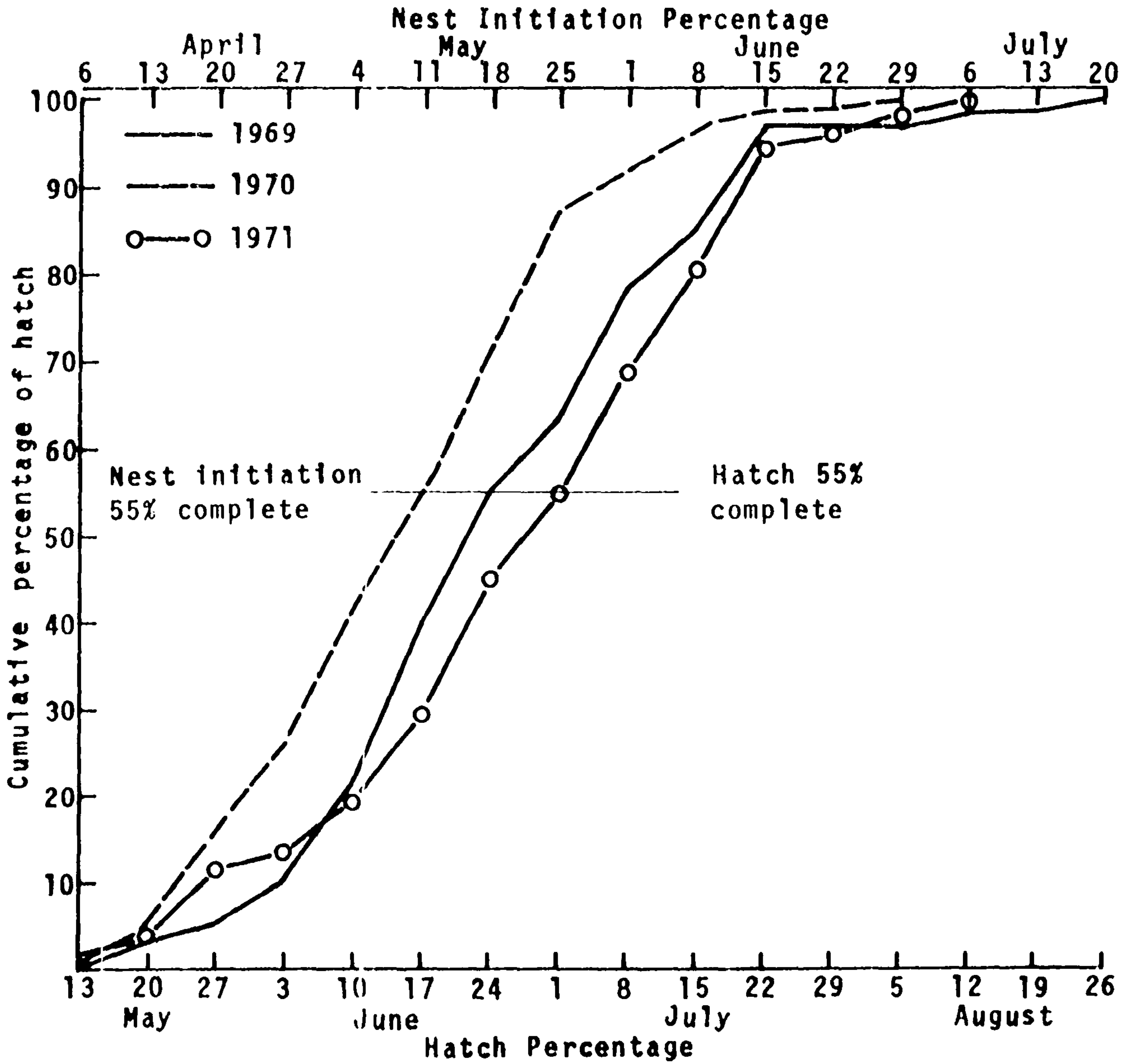
but not until 25 May in 1971 (Figure 27). Only 40 percent of the successful nests had been started by 11 May in 1969 and only about 30 percent in 1971.

The number of chicks in broods in the 4 thru 10-week old category (after Wagner et al. 1965:49) were compared from year to year and were found to reflect several differences. Broods aged at less than 4 weeks were excluded because of the more secretive behavior and relatively few observations of very young broods. Broods over 10 weeks old were excluded because of the greater tendency toward mixing of older broods and because of the difficulty sometimes encountered in distinguishing older chicks from adult birds.

Mean brood sizes were found to be 4.8 in 1969, 5.8 in 1970 and 6.1 in 1971. Tests for differences between means showed mean brood sizes in 1970 were larger than in 1969 ($P < 0.025$) and those of 1971 were larger than in 1969 ($P < 0.05$). Mean brood sizes in 1970 and 1971 were not found to be different ($P > 0.40$).

The distribution of brood sizes against age and their respective regressions (Figure 28) reveal further differences between years in brood size characteristics. Tests of linearity were not significant in 1969 ($P>0.10$) or 1970 ($P>0.05$), but were in 1971 ($P<0.05$). These results cannot be accepted at face value, however. Most conspicuously, the 1970 regression slope was positive rather than negative. With respect to any given brood this is impossible, of course, because after the brood has hatched mortality will cause it to become smaller. Thus, it is obvious that brood mixing took place to a great extent in 1970, when the population

Figure 27. Cumulative percentages of initiation of successful nests and hatch of pheasant broods observed on Hamilton County study area in 1969, 1970 and 1971.



Nest Initiation Percentage
April
May
June
July
6
13
20
27
4
11
18
25
1
8
15
22
29
6
13
20
100
90
80
70
60
50
40
30
20
10
1969
1970
1971
Cumulative percentage of hatch
Nest initiation
55% complete
Hatch 55%
complete
13
20
27
3
10
17
24
1
8
15
22
29
5
12
19
26
May
June
July
August
Hatch Percentage

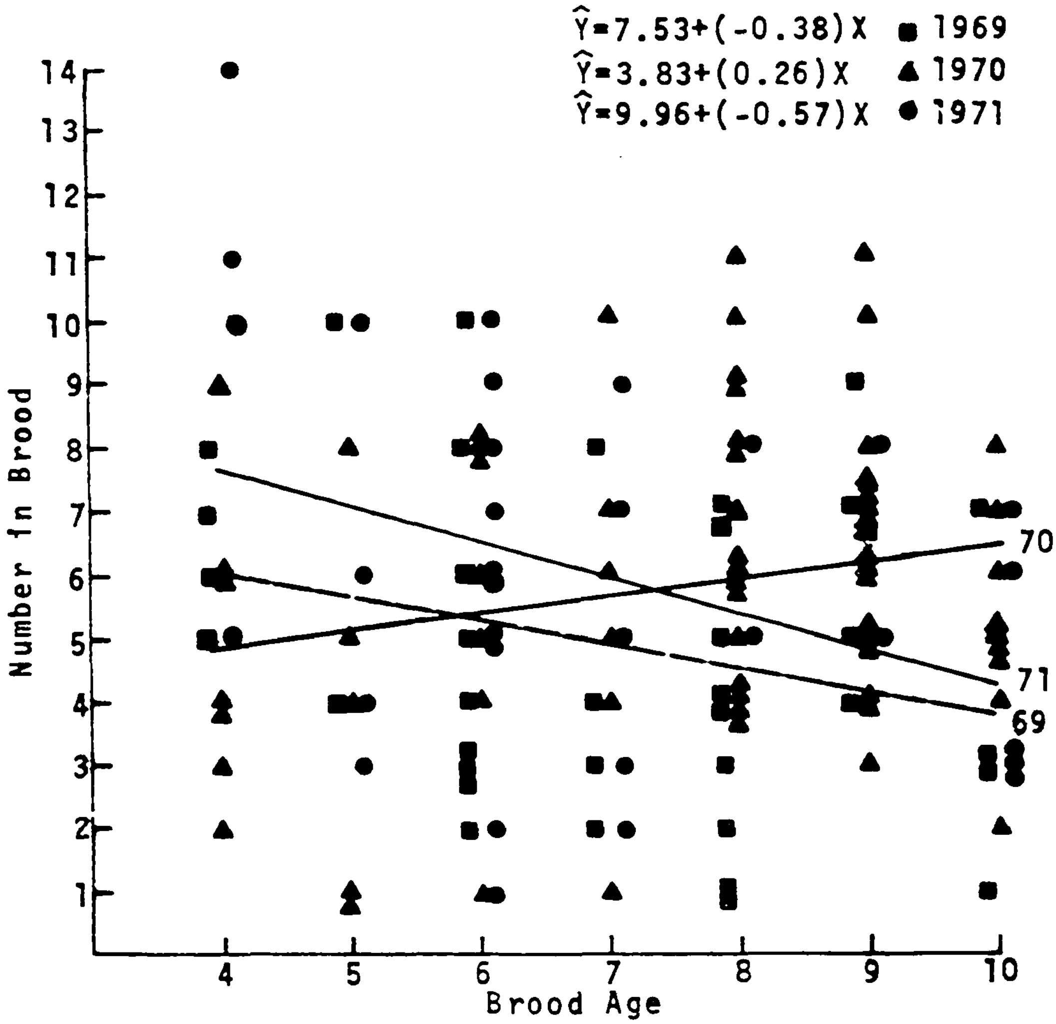


Figure 28. Size of broods 4 thru 10 weeks of age observed on the Hamilton County study area in 1969, 1970 and 1971. Brood sizes refer to size at initial observation and no duplicate observations are included.

density was the highest of the 3 years. In 1969 and 1971 brood sizes became progressively smaller as would be expected, but it is not possible to establish the extent to which brood mixing occurred and masked the decimation rates over the entire population of individual broods. The slope of the regression in 1971 was greater than in 1969, and suggests that over the 6-week period brood sizes declined by about 3 chicks in 1971 but only by about 2 chicks in 1969.

Pheasant call counts showed an increase in the population of males from 1970 to 1971 (Table 9). The amount of the increase might not have been as large as the results indicated, however, due to the 1970 counts having been made further past the peak of pheasant crowing activity than were the 1971 counts. Some increase might be expected subsequent to the increase in the 1970 late summer population over 1969, but the 1970 hunting season may have been an even greater influence.

The period September-November 1970 constituted one of the wetter Iowa autumns according to the November, 1970 Special Weather Summary published by the U.S. Department of Commerce (page 178). This would have the effect of fewer crops being harvested during the early part of the hunting season with a resulting lowered total pheasant harvest. Hen population levels would be relatively less affected by the extent of the fall pheasant harvest (only male pheasant can be legally harvested in Iowa). Call count surveys were not made in 1969.

Analyses of all parameters of pheasant population levels and characteristics consistently show 1970 to have been a year of good reproductive success and 1969 and 1971 to have been years of only fair

Table 9. Maximum number of pheasant calls heard at each stop on Hamilton County study area in 1970 and 1971. 1970 counts were made between 17 May and 24 May, 1971 counts between 28 April and 16 May. Each stop was surveyed twice

Stop number[a]	1970	1971	Stop number	1970	1971	Stop number	1970	1971
1	42	43	12	24	46	22	23	34
2	42	54	13	38	42	23	34	46
3	27	27[b]	14	28	33[b]	24	20	35
4	11	29	15	13	34	25	19	41
5	31	40	16	15	23	26	16	37
6	20	29	17	11	17	27	26	39
7	29	38	18	14	24	28	18	56
8	21	24	19	12	29	29	19	38
9	28	37	20	28	45	30	10	23
10	19	37	21	26	29	31	27	40
11	27	47						
						Mean	23.2	36.0

[a]Location of each stop is shown in Figure 10.

[b]Noise interference.

reproductive success. This conclusion is based on the evidence that (a) the number of hens in the breeding population was about the same in all years; (b) more chicks, broods and chicks per hen were observed in 1970 than in 1969 or 1971; (c) more hens were successful in hatching and rearing broods in 1970 than in 1969 or 1971; (d) the 1970 hatching season started and ended earlier than in the other 2 years, and; (e) brood sizes were larger in 1970 than in 1969, and at the end of the rearing season were probably larger than in 1971.

A census of roadsides and field units of nesting cover was conducted on 12 July 1971 to provide data that would indicate the minimum quantity of undisturbed cover on the study area for the major portion of the 1971 nesting season. Sixty-nine percent of all nests were estimated to have hatched by this date.

All roadsides were surveyed and each segment was classified according to whether it was (0) uncut, (1) mowed only along the road shoulder, (2) mowed from the road to the bottom of the ditch, or (3) mowed from the road completely across the ditch to the fenceline (grazed roadsides were included in this category). Most roadside cover consisted of brome or bluegrass, or a mixture of the two. A total of 4960 chains was surveyed (31 miles on both sides of the road) and small deviations, such as immediately in front of dwellings, were generally discounted.

A full 85 percent of the roadsides in the 12-section study unit could be considered undisturbed for pheasant nesting purposes. Over 2200 chains (44.4 percent) had not been mowed at all, and nearly 2100 chains (41.7 percent) had been mowed only along the road shoulder. Only 100 chains (2.0 percent) had been mowed just to the bottom of the ditch and 570 chains (11.5 percent) had been mowed from roadside to fenceline. Each side of every section contained a substantial amount of undisturbed grassy cover, at least on one side of the road. Quality of the cover was generally adequate. These findings are in sharp contrast with those of Joselyn and Tate (1972:3), who reported that on a study area in east-central Illinois in 1967, over one-half of all roadsides were mowed by 15 June and over 95 percent by 1 August.

Unmowed fields and ungrazed or lightly grazed pastures were also recorded. Most of the uncut hayfields were in retired cropland programs and nearly all supported residual cover at the beginning of the nesting season. There were 8 units of undisturbed pasture (totaling 114 acres) and 9 units of uncut hay (totaling 144 acres) within the 12-section study unit, with 9 of the sections containing at least one unit of undisturbed cover. Undisturbed cover (not including roadsides) made up 3.4 percent of the study unit acreage. In addition, there were 4 units (totaling 40 acres) of uncut hayfields contiguous to the perimeter of the study area.

DISCUSSION AND CONCLUSIONS

The total absence of a positive response by hen pheasants to the experimental nesting structures in this study provides strong evidence that there is no potential for these devices in future pheasant management. In addition to this primary negative finding, however, several secondary issues warrant discussion.

The structures did not function as deterrents to pheasants as evidenced by (a) the several nests found close to structures, (b) the number of occasions when pheasants were observed in the vicinity of the structures (particularly in the instance of the hen feeding immediately adjacent to one structure), and (c) the willingness of one hen to continue her nesting efforts after a structure had been placed over her nest. On the other hand hand, the structures evidently did not provide the set of microenvironmental conditions that elicit a nest-building response from a hen seeking a nesting site. Whatever those conditions that provide a nest-building stimulus are, if they actually are definable and consistent, remain obscure.

Predator activity beneath the structures in the form of the hen carcass, the disrupted cottontail nest, the jackrabbit fur found under one structure and the removal of eggs planted under structures suggests that, had there been a positive pheasant response to the structures, there surely would have been some losses to predators. To what extent this would occur is purely a matter of speculation.

Even though artificial nesting structures have been used successfully in the management of ducks (Bellrose _et al_. 1964, Bishop and Barratt 1970, Oleinikov 1971), geese (Will and Crawford 1970), squirrels (Burger 1969), and other birds and mammals, it does not appear at this point that there is any appreciable potential for development of an artificial nesting structure for the management of pheasants. The only apparent alternative, where increased pheasant production is desired, is to provide additional undisturbed natural nesting cover.

The data here presented demonstrated conclusively that the temperature and moisture conditions under both types of structures were more temperate than conditions in both nearby and remote open cover. The mean maximum temperatures under the structures were cooler than in open cover and the saturation vapor pressure deficits under the structures were lower than in the open cover. The maximum temperature extremes reached under the structures were also lower than those reached in open cover, and did not approach lethal levels at any time. The vapor pressure deficits under the structures did, however, surpass detrimental levels on one occasion when readings were taken. It seems likely, though, that a single period of several hours when vapor pressure deficits were high would be less of an influence on hatching success than several hours when temperatures were extremely high. In a general sense, the structures demonstrated the beneficial effects that a broad-leaved vegetative canopy mixed with grasses would have in contrast with nesting cover comprised of grasses only. Any protection against direct solar radiation would serve as a deterrent to harmful temperature extremes.

Two points are clearly evident from this study. First, weather conditions in central Iowa during the pheasant reproductive season in 1969, 1970 and 1971 varied markedly, and second, pheasant reproductive success was definitely greater in one year of the study than in the other two years. The implication is that the moderate climatic conditions in 1970 were more nearly optimum for pheasant reproduction than in the abnormally cool and wet year of 1969 and in the abnormally hot and dry year of 1971.

In the early spring of 1970 the critical pre-nesting period of 20 April through 10 May (Wagner et al. 1965:78, Stokes 1968:871) was significantly warmer than in 1969 or 1971. In addition, the 1971 season had a 28-day period of no precipitation from 20 March to 17 April, and the 1969 season had a span of 21 days from 1 March to 21 March with only 0.05 inch of precipitation recorded on one day. The combination of cool and dry conditions that prevailed in those two years would have tended to have retarded the growth of new vegetation in the early part of the nesting season. This was noticeably the case in 1971. Hanson (1970:717) has observed: "The life form of the cover seems critical to the early-nesting pheasant hen, for the greater the plants' height, or density, or both, the more the hens tended to use them for nests."

The facts that the mid-point of the hatch of the 1969 pheasant crop occurred one week later than did the 1970 mid-point, and that in 1971 it was two weeks later than in 1970, bear out the significance of the different weather patterns in those 3 years. Of particular interest is the point that, from 20 through 28 April 1970, there were eight consecutive days when the soil temperature recorded was higher than the preceding day. This run of increasingly warm days, rather than any absolute temperatures involved, may well have been the stimulus that started general nesting activity in 1970. With respect to the advantages of an early nesting season, Baskett (1947:23) has pointed out that early clutches average larger than later ones and the success of early nests lessens the probability of hens being killed during hay mowing. It could be added that early nesting also lessens the potential for nest exposure to intense solar radiation. One further possibility, though speculative only in nature, is that earlier favorable environmental conditions may operate to the greater advantage of inexperienced hens nesting for the first time. In contrast, one might expect that the older hens, having fully matured and having had a prior nesting experience, would proceed with nesting activities at an early data, regardless of climatic and cover conditions.

Within the nesting season proper several instances of extremely high temperatures, as indicated by soil temperatures, occurred during the 3-year study, most notably in 1971. Readings of 95° F and higher were commonly recorded, and as early in the year as 6 June 1970 and 18 June 1971. But the singularly outstanding period of high temperatures was registered in 1971, when 108° F was recorded on 23 June, and daily highs thereafter were at least 97° F until 28 and 29 June when they were 112° F and 105° F respectively. No comparable period of sustained high temperatures of that extreme occurred in 1969 or 1970. Maximum temperatures recorded in open nesting cover from 23 through 29 June 1971 ranged from 84° F to 113° F, depending on location, and maximum ambient temperatures during that same interval were between 88° F and 96° F.

The reported nest attentiveness patterns of incubating hens during daytime hours is somewhat variable, but Klonglan _et al_. (1956:176) have stated: "The majority of the inattentive periods occurred between 3:00 and 6:00 p.m." These findings were supported by Ridley (1957:40) and Kuck _et al_. (1970:628). Ridley (1957:50) also stated that only about 4 percent of the variation in length of daily inattentiveness should be attributed to the influence of maximum temperature. It should be taken into account, however, that if hen pheasants leave the nest in response to only extremely high temperatures, that would be the precise time when high temperatures could have the greatest effect on incubating eggs. On the other hand, during a study in New Zealand, Westerskov (1956:413) reported that, "The time when the hen left the nest did not conform to an 'inherent' rhythm but appeared to be correlated with daily maximum temperatures." But his interpretation was that, if air and ground temperatures rise above egg temperatures and if the eggs are exposed to direct sunlight, the hen is buffering the eggs against higher temperatures rather than incubating them.

Kessler (1962:705) reported from one study that "...hen pheasants spent a greater amount of time off the nest during the earlier and later stages of incubation than during the intermediate period." After a nesting study in southwestern Iowa where only 13 of 209 nest temperature readings were judged potentially critical to the incubation of eggs, Klonglan (1962:253) further noted that: "Most nests on the study area were apparently safely placed relative to potential ill effects from intense insolation." I know of no work conducted specifically to establish the tolerance limits of incubating hen pheasants to high temperatures or intense solar radiation.

That some pheasant eggs in some seasons are affected by high temperatures seems almost certain. Schulte (1972:11) for example, using deserted pheasant nests in Minnesota for the collection of data, reported the eggs were often heated significantly above air temperature, once by 27° F. Yeatter (1953:7) found that by heating unincubated pheasant eggs to between 73° F to 88° F, followed by normal incubation, hatchability was reduced by 14 to 44 percent, the reduction increasing with the higher temperatures. In contrast, Deucher (1952), working with domestic hen eggs, found no effects from heating unincubated eggs to 114° F for 5 hours. He did, however, report various rates of embryo mortality and crippling by exposing eggs incubated for 19, 16, 12 or 7 hours to temperatures of 114° F for either 3 or 5 hours, with up to 80 percent of the embryos being affected.

Incubation at above-normal temperatures retarded the growth of the embryo and added about one day to the incubation period of pheasant chicks according to Romanoff (1934:12). In a subsequent paper Romanoff et al. (1938:22) presented data showing that embryo mortality is more critical at 4, 12 and 22 days of incubation than at other times, but in their experiments involving 1402 embryo mortalities, between 5 and 6 times more mortalities occurred at 22 days of incubation than on day 4, the day of second highest mortality.

The data for the Hamilton County study area indicates (Figure 26) that the pheasant hatch in 1971 dropped off after the week of 24 June without attaining a level equal to even the secondary peaks of 1969 or

1970. Considering the finding of Romanoff et al. (1938:22) that the twenty-second day of incubation is the one on which embryo mortality is most likely to occur, it seems that the extreme heating that occurred from 23 through 29 June 1971, and the accompanying high vapor pressure deficits, quite possibly depressed the pheasant hatch during the week that would otherwise have provided the season's peak of hatch (the same week as in 1970).

Precipitation patterns, as well as temperatures, varied widely in 1969, 1970 and 1971 (Figure 24). During the wet summer of 1969, there were 5 periods when more than 2 inches of rain fell within 3 days (an arbitrary indicator of "excessive" rainfall). The minimum 24-hour low air temperature recorded for any of those 5 periods was 52° F on 1 May. In contrast, there were only 2 such periods in both 1970 and 1971. The first wet period in 1971 did not begin until 30 June and in 1971 not until 27 July. Associated minimum low temperatures were 55° F in 1971 and 58° F in 1970. Thus, the frequency and distribution of heavy rains, and the associated low temperatures, that might have affected pheasant reproduction appear to have been limited to the 1969 season. The most notable precipitation phenomenon of the 3 years, however, was the near-normal frequency and amount of rainfall in 1970 and the high pheasant reproductive success that accompanied it.

Precipitation, being a direct influence on atmospheric moisture levels through evaporation and transpiration, is necessarily a factor in daily vapor pressure deficits and relative humidity. Humidity, in turn, affects pheasant eggs in several ways (Romanoff 1934:23), particularly through control of the rate of moisture evaporation from the egg. High humidity seals the pores of the eggshell, and retards the exchange of gases. Low humidity, on the other hand, induces high evaporation losses (Romanoff 1934:23) which, if sufficiently great at pipping time, can cause the embryonic and shell membranes to become dry and attached firmly to the embryos, some of which may be unable to free themselves and subsequently die (Romanoff et al. 1938:31). From his experiments, Romanoff (1934:31) concluded: "The mortality of pheasant embryos was the lowest at high humidity, and then gradually increased towards low humidity," and that "...the pheasant embryo is susceptible to low humidity only..." He further stated (p. 35) that "...the best growth of pheasants was of those which had been hatched from the eggs exposed continuously to 70 percent or more relative humidity." Over the duration of the Hamilton County study, however, it is doubtful that sustained low humidity conditions could have occurred to a sufficient extent to affect hatching success, with the exception of the extreme period of 23 through 29 June 1971.

The tolerance limits of pheasant chicks for high temperature-low moisture conditions are little better delineated than for pheasant eggs. In an experiment conducted in South Dakota, Harris (1950) did learn that "...pheasant chicks are able to thrive without water in a liquid form from the time of hatching at least through the first 32-day period, if they are able to find a sufficient quantity of insects, worms, etc. from which they can obtain the necessary moisture." The question that comes to mind, however, is to what extent suitable invertebrates are available to chicks during dry summers.

In conclusion, it appears from the evidence available, that short-term climatic extremes are far more of a factor in influencing annual pheasant reproductive success than are longer-term climatic means within a reproductive season. Further, in years and in local areas in which extremes of untimely hot, cold, dry or wet conditions are absent, maximum pheasant reproductive success and population increase can be anticipated.

SUMMARY

High temperatures and low humidity adversely affect ring-necked pheasant (Phasianus colchicus) incubation. The shade-producing canopy of broad-leaved weeds that would temper the incidence of solar radiation on unattended pheasant eggs is generally absent in many locations where some pheasants occur. Providing a substitute for the missing canopy seemed to be one possible way to create a microclimate that would be attractive to hen pheasants seeking a site for a nest. The objectives of this study were to (a) evaluate the response of pheasants to artificial structures intended to create a microenvironment preferred for a nesting site, (b) monitor temperature and moisture conditions under the structures and relate them to conditions in natural cover, and (c) measure the pheasant population levels on the study area and relate them to temperature and moisture conditions during the reproductive season.

More than 100 each of two types of nesting structures were placed on a study area in southern Hamilton County, Iowa, in 1970 and 1971. Temperature and moisture conditions under the structures and in natural cover were monitored in 1971 and air temperature, soil temperature and precipitation data published for 1969, 1970 and 1971 were utilized. Pheasant brood counts and spring call counts were made.

No indication of a positive response to the structures by pheasants was found during the entire study, although several nests were found in close proximity to structures. One nest, containing 11 unincubated eggs,

was discovered within 3 1/2 feet of a flat structure on 6 May 1970, but was unsuccessful.

A flat structure was placed over a nest after the hen was flushed from it on 2 June 1971. Five more eggs were laid in the nest and the hen was seen on it on 28 June. By 1 July the nest had been destroyed by a predator.

The carcass of a hen pheasant was found 22 July 1970 under a hut structure where it presumably had been dragged by a predator.

The 1969 reproductive season was cool and wet, the 1970 season was normal in terms of temperature and precipitation and the 1971 season was hot and dry. Temperatures were sampled in 5 different locations in 1971 in ground cover of the type often used by nesting pheasants. The highest maximum (113° F) and mean (80.7° F) temperatures were recorded in open cover and the lowest in cover under the nesting structures.

The drying capacity of the air, as measured by vapor pressure deficits, was found, at some time during 1971, to exceed levels presumably favorable for pheasant embryo development in all cover situations where wet- and dry-bulb readings were taken. The greatest deficits were recorded on 28 June on the Hamilton County study area. The readings on that date at 1415 hours were 1.302 (in. Hg.) in open cover, 1.264 under the flat structure, 1.118 under the hut structure and 1.134 in the air 3 feet above ground level. The Hamilton County open cover mean deficit was greater ($P < 0.01$) than the mean deficits under either the hut or flat structures.

Maximum soil temperatures recorded during the incubation season of 15 April thru 25 July in 1971 were 112° F (28 June), 108° F (23 June) and 105° F (29 June). By comparison, in 1970, the maxima were 106° F (2 July), 105° F (14 July) and 104° F (14 June), and in 1969 highs of only 102° F (16 July) and 98° F (22, 24, 25 July) were recorded. Mean temperatures from 20 April to 10 May in 1970 were warmer ($P < 0.05$) than in both 1969 (by 8.4° F) and 1971 (by 5.1° F).

Total precipitation during the period 1 March to 31 August decreased from a high of 27 inches in 1969, to 19 inches in 1970, to 14 inches in 1971. Normal for that period is 19.71 inches.

On 2 June 1971 a hen was flushed at 1241 hours (C.S.T.) from a nest containing nine eggs and located at the bottom of a roadside ditch in knee-high brome and bluegrass. Wet- and dry-bulb temperature readings, taken alternately in the nest and in cover 12 inches from the nest, revealed that the drying capacity of the air in the nest bowl was greater than the drying capacity in the cover 12 inches from the nest ($P < 0.05$).

Summer roadside survey results showed that pheasant population levels on the study area were about equal in 1969 and 1971, but were significantly higher in 1970 than in either of those years. The number of chicks observed (after duplicate observations were deleted) was 284, 504 and 289 in 1969 thru 1971. There were significantly more ($P < 0.005$) chicks per hen in 1970 (6.51) than in 1969 (4.26) or 1971 (4.24).

A census on 12 July 1971 showed that, through that date, a full 85 percent of the roadside cover on the 12-section study unit could be considered undisturbed for pheasant nesting purposes.

Even though artificial nesting structures have been used successfully in the management of other birds and some mammals, it does not appear that there is any appreciable potential for development of an artificial nesting structure for the management of pheasants.

From 20 through 28 April 1970, there were eight consecutive days when the soil temperature recorded was higher than the preceding day. This run of increasingly warm days, rather than any absolute temperatures involved, may well have been the stimulus responsible for the earlier successful nesting activity that took place in 1970, compared with 1969 and 1971. One singularly outstanding period of high soil temperatures was registered in 1971, when 108° F was recorded on 23 June, and daily highs thereafter were at least 97° F until 28 and 29 June when they were 112° F and 105° F respectively. No comparable period of sustained high temperatures of that extreme occurred in 1969 or 1970.

The data for the Hamilton County study area indicated that the pheasant hatch in 1971 dropped off after the week of 24 June without attaining a level equal to even the secondary peaks of 1969 or 1970. Considering that the twenty-second day of incubation is the one on which embryo mortality is most likely to occur, it seems that the extreme heating that occurred from 23 through 29 June 1971, and the accompanying high vapor pressure deficits, quite possibly depressed the pheasant hatch during the week that would otherwise have provided the season's peak of hatch (the same week as in 1970).

The most notable precipitation phenomenon of the 3 years was the near normal frequency and amount of rainfall in 1970 and the high pheasant reproductive success that accompanied it.

In conclusion, it appears from the evidence available, that short term climatic extremes are more of a factor in influencing annual pheasant reproductive success than are longer term climatic means within a reproductive season. Further, in years and in local areas in which extremes of untimely hot, cold, dry or wet conditions are absent, maximum pheasant reproductive success and population increase can be anticipated.

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ACKNOWLEDGMENTS

This study was supported through the cooperative efforts of the U. S. Bureau of Sport Fisheries and Wildlife and the Iowa State Conservation Commission. Special thanks are due to Dr. Arnold O. Haugen, Leader of the Iowa Cooperative Wildlife Research Unit, for his advice, counsel and patience throughout the study and in preparation of this manuscript. Valuable field assistance was provided by fellow students Dave Howell, John May, Terry Little, Bill Seitz and Mike Zagata. The help of Dr. Roger Q. Landers in the identification of plant specimens was especially appreciated. Doctor David F. Cox and Roger Mrachek provided valuable assistance in statistical analysis of the data.

The permission of many Hamilton County farm operators to erect nesting structures on their property was essential to the success of this project. I am most grateful for the generosity and friendly treatment received from Messrs. William Ahrend, Andrew Alfseike, R. C. Bennett, Clifford Boe, Glen Carlson, Jeffrey Hill, Clarence Hove, Gary Johnson, Leslie Johnson, Robert Kaiseim, Reuben Nibe, Emmit Olson, James Thorson, and Eugene Westre. Extra thanks are due Mr. R. C. Bennett for allowing me to maintain temperature recording instruments on his land. The consideration of Mr. Gerald Hoskins in authorizing me to maintain recording instruments at a convenient location on an Iowa State University farm was also appreciated.

Finally, to my wife, Lucile, and Dean, Duane and Kathy, for their direct help and unending willingness to let this endeavor come first, I will be forever indebted.

APPENDIX: PLANT SPECIES OBSERVED ON THE STUDY AREA[1]

Alfalfa	*Medicago sativa*
Big bluestem	*Andropogon Gerardi*
Bluegrass	*Poa pratensis*
Canada thistle	*Cirsium arvense*
Canada wild rye	*Elymus canadensis*
Cattail	*Typha latifolia*
Common ragweed	*Ambrosia artemisiifolia*
Corn	*Zea Mays*
Downy bromegrass	*Bromus tectorum*
Fox-tail	*Setaria faberii*
Giant ragweed	*Ambrosia trifida*
Goldenrod	*Solidago* spp.
Hackberry	*Celtis occidentalis*
Hemp	*Cannabis sativa*
Horsetail	*Equisetum arvense*
Indian grass	*Sorghastrum nutans*
Lambsquarter	*Chenopodium album*
Milkweed	*Asclepias syriaca*
Muhly grass	*Muhlenbergia cuspidata*
Mulberry	*Morus rubra*
Oats	*Avena sativa*
Ox-eye	*Heliopsis helianthoides*
Pigweed	*Amaranthus retroflexus*
Porcupine grass	*Stipa spartea*
Quackgrass	*Agropyron repens*
Queen Anne's lace	*Daucus Carota*
Red cedar	*Juniperus virginiana*
Red clover	*Trifolium pratense*
Redtop	*Agrostis alba*
Reed	*Phragmites communis*
Reed canarygrass	*Phalaris arundinacea*
Sedge	*Carex* spp.
Slender wheatgrass	*Agropyron trachycaulum*
Slough grass	*Spartina pectinata*
Smartweed	*Polygonum* spp.
Smooth brome	*Bromus inermis*
Soybean	*Glycine Max*
Squirrel-tail	*Hordeum jubatum*
Switchgrass	*Panicum virgatum*
Tall dropseed	*Sporobolus asper*
Timothy	*Phleum pratense*
Western wheatgrass	*Agropyron Smithii*
Wild parsnip	*Pastinaca sativa*
Wild plum	*Prunus* spp.
Wild rose	*Rosa* spp.
Witch grass	*Panicum capillare*
Yellow sweet clover	*Melilotus* spp.

[1]Nomenclature based on Fernald (1950).